Dental caries in medieval Britain (c. AD 450-1540) : temporal, geographical and contextual patterns

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DENTAL CARIES IN MEDIEVAL BRITAIN

(c. AD 450 - 1540):

TEMPORAL, GEOGRAPHICAL AND CONTEXTUAL PATTERNS.

by

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Ustinov College

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DECLARATION.

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ABSTRACT

Dental Caries in Medieval Britain (c. AD 450 – 1540):

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This research examines the prevalence of dental caries in Early (c. AD 450-950), Middle (c. AD 950-1150) and Late Medieval Britain (c. AD 1150-1540). Eighty-eight data-sets (for 79 sites, 14,296 skeletons) were compiled from published and unpublished skeletal reports, but due to the limitations of the data available only 53 data-sets (for 46 sites, 9,136 skeletons) could be included in analysis. Sites were distributed across the country, but the majority were located in the south and east of England, and the Late Medieval sites were predominantly in urban areas. Caries prevalence in teeth from adults, males, and females are compared between: the main Medieval periods; chronological sub-divisions within the Early and Middle Medieval periods; different Late Medieval cemetery types (church, monastic, hospital and cathedral); non-monastic and monastic samples through time and within each period; different religious orders; coastal and inland sites; and five regions. The data are interpreted using a biocultural approach.

A low caries prevalence was observed in Early and Middle Medieval monastic compared to non-monastic samples, but the Late Medieval monastic caries prevalence was significantly higher than both preceding monastic samples and the contemporary church sample; hospital sites had a particularly high caries prevalence. Early Medieval coastal sites had a low caries prevalence compared to inland sites, but the trend was reversed in the Late Medieval period; these data are discussed in relation to the consumption of marine fish. Changes in the pattern of sex differences in caries prevalence were observed.

The limitations of the data are discussed, together with a critique of the quality of data available in currently available skeletal reports.

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1 INTRODUCTION

1.1 Skeletal Reports and their Importance.

From the 1960s onwards a substantial number of sites yielding human skeletal remains have been excavated and analysed in Britain, meaning that a large quantity of data is now available in the form of published (and unpublished) skeletal reports. These skeletal reports have provided data on assorted disease categories for each site, and several have included a comparison of their results with those of sites previously excavated. The extent of the comparison varies from providing detailed tables listing the prevalence of a particular disease in several other sites (for example Anderson and Andrews, 1997), to mentioning the prevalence of that disease in a couple of other sites in the text (for example Boocock, *et al.*, 1995), to no comparison with other sites at all (for example Fielden, 1978). In the majority of cases the prevalence rate of the disease in question in the skeletal material being recorded is simply said to be higher, lower or similar to the prevalence of that disease in other sites of the same period/ type/ region. The comparisons made in these reports tend to be fairly limited in scope, which is a fair reflection of the fact that the purpose of such reports is to present data on a new skeletal collection and place it in context and not to launch into an in-depth discussion of every single disease category. These comparisons also tend not to reach a wide audience because few people with a general interest in the prevalence of a specific disease in different periods have the time available to wade through multiple skeletal reports, many of which are unpublished, in search of data, and are more likely to refer to a source where they know such data is compiled and discussed.

The compilation of data from skeletal reports is therefore important. Firstly, it makes the data more accessible to other researchers, meaning that they can easily target the reports they need. This is especially valuable for the rarer diseases, such as gout or poliomyelitis, which do not occur in every skeletal population and where searching through numerous skeletal reports on the off chance that one will include data on that disease is particularly tedious. However, it is equally useful for more common diseases, such as dental caries, where not all sites may have presented data in a similar format. In these cases an individual can see at a glance which skeletal reports provide the right kind of data for their purpose, and also gain an impression of the range of expression of that disease. Such compilations of data can, therefore, assist in the formation of research questions and research designs, for example through discovering trends in the data that may warrant more detailed investigation, or through providing a quick and easy way for a researcher to identify collections that satisfy certain criteria and so have the potential for inclusion in a research project. Lack of awareness of the existence of some collections may contribute to the fact that they are less commonly studied than others, which in turn contributes to the general invisibility of these collections.

Secondly, the skeletal reports provide data on individual sites, and these data need to be compiled and discussed in a meaningful way if our understanding of health in the past is to be deepened. Without this process there is no context within which to place new data, or framework available to help evaluate the position of each existing sample. Something needs to be done with the data collected, otherwise there is little point in collecting it.

Thirdly, the process of compilation and comparison, and the associated development of new research questions, highlights issues concerning the way in which data are recorded and presented in the skeletal reports. These data form the basic record of the human remains from that particular site, which becomes available to future workers in the field who may well not have access to the original skeletal material. This may be because access to the material is carefully controlled, because material has been lost or damaged over the years, because the researcher does not have the time or funding that would allow them to visit collections and record the material themselves, or because the material has been reburied. It is absolutely vital, therefore, that these data be recorded and presented in as full and accurate a manner as possible, in such a way that others can use the raw data for their own research if necessary. This requirement is becoming ever more pressing considering the recent trend towards unquestioning reburial of skeletal remains excavated from archaeological sites. It is during the process of gathering data from skeletal reports for the purpose of answering specific research questions that inadequacies in the current methods of data collection and presentation are exposed. These inadequacies need to be addressed so that in the future better and more useful skeletal reports can be produced, benefiting the discipline as a whole.

Research making use of the data present in skeletal reports is essential if the discipline of biological anthropology is to progress in Britain. Recently, Roberts and Cox (2003) attempted an ambitious study to examine the evidence for disease in British archaeological populations, and in order to achieve this they collected data on a multitude of diseases from a considerable number of skeletal reports. Work on such a grand scale cannot hope to be achieved through collecting all the data directly from the skeletal material itself. Even if all the material were still available to be studied, which it is not, the logistics of such an undertaking would be so complicated and the process so time consuming as to make the task virtually impossible. Their book tackles a range of diseases across a broad time span, bringing together data, which had, up until now, largely been uncompiled. Such an exhaustive study has been long overdue, and the intention of the authors was to bring together much of the data that had been gathering in isolated skeletal reports and explore what patterns that data revealed about health and disease in the past in relation to cultural and natural factors.

1.2 Aims.

Originally the aim of this research was to conduct a study of the geographical distribution of disease in Medieval Britain, from the mid fifth to the mid sixteenth century AD, using a Geographical Information Systems (GIS) computer program (ArcGIS 8.2). The large number of excavated cemetery sites dating to the Medieval period provides a substantial sample with which to examine disease patterns. In addition, much is known from archaeological and historical sources concerning the social and economic circumstances of the population in these periods, enabling the biological and cultural data to be incorporated and thus enhancing interpretation. Studying the Medieval period allows health to be examined at the transition from a predominantly rural subsistence base to one increasingly dependent on the development of towns and trade. Social class and religious practices are also well documented for these periods and will have had an impact on health. The only way such a study could be achieved would be to take the same approach as Roberts and Cox (2003) and collate the data already present in skeletal reports. It was felt that the quality of these data should be evaluated, firstly, because these data would form the basis of the current research, and secondly, these data are integral to the study of biological anthropology in general; the importance of skeletal reports as a source of data can only increase if the current inclination towards reburial increases.

With these aims in mind, data on a variety of diseases from a large number of sites were compiled from skeletal reports. Data were collected for inhumations, but cremations were not included as the relevant information on pathology is less likely to be recovered and the results may therefore be biased. Aside from issues of inter-observer error and differences in diagnosis between individuals, variation was expected in the way information was recorded and presented in the reports. It was realised that this diversity would cause difficulties in collecting comparable data, but it was hoped that it would still be possible to obtain enough serviceable data to make the approach worthwhile. However, the issues concerning quality and comparability of data were more prominent than anticipated, and the quality of the data obtainable from the skeletal reports was much worse than expected. This lead to focussing research on one disease in particular: dental caries. This was the disease category that was represented by the most consistent data between sites, and this was the reason it was selected for analysis. This, coupled with other problems concerning the acquisition of relevant geospatial data, meant that the original aims had to be modified.

It was decided to investigate variation in the prevalence of dental caries in Medieval populations in some detail, and examine aspects that have not hitherto been considered. Previous studies have noted a lower caries prevalence in Early Medieval Britain compared to the preceding Romano-British period (for example, Brothwell, 1959; Hardwick, 1960; Moore and Corbett, 1971, 1973, 1975; Corbett and Moore, 1976; Freeth, 1999), but no studies have investigated caries prevalence within this broad time-span in more detail. Therefore, the research had the following aims:

- To examine chronological changes in caries prevalence between subdivisions of the Medieval period. The Early Medieval period was expected to show a low caries prevalence, with an increase in the Late Medieval period.

- To examine the relationship between status and caries prevalence in the Late Medieval period through comparing skeletal remains excavated from different contexts (church, monastic, hospital and cathedral). The church and cathedral sites were expected to show a lower caries prevalence than the monastic and hospital sites.

- To compare non-monastic and monastic sites between the Early, Middle and Late Medieval periods to investigate secular and monastic changes through time. A greater change was expected in the monastic context.

- To explore any differences between the Late Medieval religious orders through comparing caries prevalence between skeletal remains excavated from different monastic contexts.

- To compare caries prevalence between coastal and inland sites in the Early, Middle and Late Medieval periods, as previous studies have associated low caries prevalence with the marine-based diet of coastal sites (for example, Walker, 1986; Littleton and Frohlich, 1993; Larsen, *et al.*, 1992; Hutchinson, *et al.*, 1998). Early Medieval coastal sites were expected to have a low caries prevalence compared to those inland, but the difference was expected to disappear in the Middle and Late Medieval periods.

- To examine regional trends in caries prevalence within and between the Early, Middle and Late Medieval periods.

Within each of these sections caries prevalence is examined in teeth from adult individuals, and sex differences in caries experience are explored. The final aim was:

- To evaluate the quality of data presented in skeletal reports.

1.3 Structure of the Thesis.

A general background to palaeopathology and medical geography is given in Chapter 2. The history and development of palaeopathology, the sources of evidence, and methods of investigation are discussed along with the limitations of the skeletal sample and evidence for disease. The biocultural approach to palaeopathology entails the combination of the biological data recorded from the skeletal remains with the cultural and environmental data retrieved from archaeological excavations and historical documents (Roberts and Cox, 2003). In many ways this approach is similar to that taken by medical geographers, who are interested in examining the effect of the environment on the health of populations. This association of environment with health has been in existence for centuries, and the origins and evolution of this concept is examined.

Chapter 3 discusses dental caries: what it is, how it happens, and what factors influence its development. The clinical literature on the relationship between diet, trace elements, and dental caries is reviewed. Studies of caries prevalence in relation to diet and trace elements in archaeological populations are assessed, both for Britain and elsewhere, and sex differences in caries prevalence are discussed. Chapter 4 provides a historical framework and background to the Medieval period, with a particular focus on evidence for diet in different time periods and social groups. The potential of the diet to cause dental caries is discussed.

The material used as the source of data for this research is introduced in Chapter 5, and the methods by which data were collected and analysed are outlined. Chapter 6 presents the results of the analysis, focussing first on the type of data obtained from the skeletal reports before turning to the results on the caries data themselves. The latter are presented in six sections:

1. Chronological change between the Early, Middle and Late Medieval main periods and within the Sub-Periods of the Early and Middle Medieval periods;
2. Late Medieval cemetery types (church, monastic, hospital and cathedral);
3. Chronological change between non-monastic and monastic sites;
4. Variation in caries prevalence in different religious orders;
5. Differences in caries prevalence between coastal and inland sites within each main period;
6. Regional variation in caries prevalence.

Chapter 7 addresses the limitations of the study before discussing the results. The evidence for dental caries from skeletal reports is considered first, and then the results on caries prevalence are examined in the order above. Finally, Chapter 8 summarises the conclusions drawn from this study, with suggestions for future work. The quality of data available in current published and unpublished skeletal reports is critiqued and recommendations for improved practice are made.

2 HEALTH, DISEASE AND THE ENVIRONMENT

2.1 Introduction.

The concept of health is surprisingly hard to define. Several authors, for example Learmonth (1988) and Meade and Earickson (2000), have examined various definitions and explored the difficulties involved. The fact that the essence of health incorporates a positive state of well being rather than being merely a negative absence of disease has been recognised by the World Health Organisation (cited in Meade and Earickson, 2000). However, social and cultural interpretations of what constitutes a healthy state will vary with what a given population believes to be normal, and so what one population perceives as disease, another will accept as part of the natural human condition (Lebret, 1995; Learmonth, 1988). For practical purposes, it is difficult to escape the notion of health expressed as an absence of disease. Therefore, despite the limitations, measurement of the amount and severity of disease is often used when attempting to evaluate the health of a population.

Many definitions of health include the idea of balance with the environment. For example, Howe and Phillips (1983: p34) describe health as being "a state of adjustment or harmony between man (his living tissues, cells and components of cells) and his physical, biological and socio-cultural environment". This is essentially the same as Angel's (1981: p509) view of health as "a balance of mankind with disease parasites and environmental stresses". In this context, disease can be defined as "a reaction between individuals and the stresses, strains and other adverse factors of their physical, biological and social milieu, the response being conditioned by the genetic make-up… of the individual" (Howe, 1997: p1). Aside from intrinsic genetic factors, an individual's response to the threat of disease will be modified by their age, sex, nutritional status and the effectiveness of their immune response (Ortner, *et al.*, 1992; Ortner, 1998). For example, individuals suffering from malnutrition are often not able to respond to the threat of infectious disease, such as measles, as effectively as a person who has access to an adequate diet (Meade and Earickson, 2000).

The environment can influence health through a variety of biological, physical and human factors (Howe, 1997; Meade and Earickson, 2000). Infectious organisms are widespread, and include bacteria, viruses, protozoa, rickettsiae, and fungi as well as macroscopic parasites, such as worms. Some are communicated directly from person-to-person (for example, measles), others require an animal vector (for example, malaria), and yet others may be transmitted via water (for example, cholera), soil (for example, tetanus) or air. In addition to organic pathogens (disease-causing agents), inorganic substances can cause ill health when toxic matter is either present or overabundant, or when sufficient essential elements are unavailable (Ortner, 2001), for example the association of goitre with lack of iodine in the drinking-water (Howe, 1997). Physical factors of the environment, including climate, rainfall, temperature, humidity, sunshine, wind and elevation will determine which pathogens are present and how successful they are at transmission, for example the mosquitoes that transmit malaria require certain environments in order to survive and breed and if the mosquitoes are absent then so is malaria (Howe, 1997; Ortner, 2001). They also influence the amount of necessary elements and potentially toxic materials available, such as the necessary action of sunshine for the production of Vitamin D in the human body (Howe, 1997; Ortner, 2001; Meade and Earickson, 2000). To a large extent, these factors will also control the extant plant and animal populations, which will affect the quantity and type of food obtainable. Certain crops will grow well in particular locations in response to favourable climatic conditions, and in areas where these conditions are absent it is difficult to grow the crop, for example the difficulty in growing wheat in highland areas of Britain (Reed, 1990).

Nutrition, as has already been mentioned, will alter an individual's susceptibility to disease; those with poor nutrition suffer increased vulnerability to infection and deficiency diseases (Meade and Earickson, 2000). Poverty, poor nutrition and disease are often linked, being conditions largely dependent on each other, and this association is often found in the case of tuberculosis, which is closely connected with the crowded living conditions and poor sanitation present in urban slums (Dormandy, 1999). Humans adapt the environment to suit their needs, such as flooding an area to create a reservoir, and through doing so they change the existing balance between themselves and the pathogens and alter their disease experience, where in this example the new reservoir generates ideal conditions for an explosion in the mosquito population and thus an increase in malaria (Meade and Earickson, 2000). Cultural behaviour will also affect disease transmission, and behavioural roles, varying with sex, age, and/or class, will govern each individual's risk of exposure to certain diseases (Meade and Earickson, 2000).

All these environmental and cultural factors are inherently intertwined, and exert a complex influence on the pattern of health and disease experienced by a population. Therefore, the types and distribution of disease evident within a population are indicative of the environment in which that population lived and the socio-cultural behaviour practiced. This fundamental concept is the principle by which medical geography explores disease distributions in modern populations in an attempt to clarify the roles of different factors in disease causation. An understanding of the fact that disease reflects environmental conditions and human behaviour also forms the basis of many palaeopathological studies, which attempt to add to, complement, and reinterpret the evidence on ancient populations obtained from other archaeological or historical sources. The development, methodology and limitations of palaeopathology will be outlined below.

2.2 Palaeopathology.

> "The pattern of disease or injury that affects any group of people is never a matter of chance. It is invariably the expression of stresses and strains to which they were exposed, a response to everything in their environment and behaviour. It reflects their genetic inheritance (which is their internal environment), the climate in which they lived, the soil that gave them sustenance and the animals or plants that shared their homeland. It is influenced by their daily occupations, their habits of diet, their choice of dwelling and clothes, their social structure, even their folklore and mythology" (Wells, 1964: p17)

Pathology is the "scientific study of tissue abnormality" resulting from disease (Manchester, 1987: p168), and therefore palaeopathology is concerned with studying the evidence for ill health and trauma in ancient populations (Lovell, 2000; Roberts and Manchester, 1995). For many, the main incentive for its pursuit is the close association between the environment and disease, encapsulated by Calvin Wells above and discussed in the previous section, for without an understanding of the environmental factors disease data cannot be interpreted. Information on how a population interacts with the environment can be gained through careful interpretation of the evidence for the diseases experienced by that population. Research also focuses on the repercussions of disease for human populations, including the evolutionary consequences of the interaction between pathogens and humans (Miller, *et al.*, 1996; Ortner, *et al.*, 1992), such as the changing expression of the treponemal diseases and whether this may be related to alterations in human cultural behaviour (Hackett, 1967). In addition, palaeopathology can provide evidence for the ways in which past humans have adjusted to, or altered, their environment (Roberts, 2000). For example, many studies (reviewed by Larsen, 1995) have been carried out on how the transition to agriculture from a hunting and gathering existence has impacted on the health on human populations, usually finding increased levels of dental caries, more evidence of undernutrition and stress, higher infection rates and shorter adult stature. The interpretation of these results suggests that this transition is not as beneficial to the human condition as previously believed. Another aspect involves the tracing of the temporal and geographical history of specific diseases through their diagnosis in ancient human remains (Miller, *et al.*, 1996), including the debate on the origins of venereal syphilis (discussed in Aufderheide and Rodríguez-Martín, 1998). Palaeopathological investigation can also supply a context for modern epidemiological studies and help resolve current medical issues, (Steckel and Rose, 2002b; Roberts, 2000). For example, the prevalence of dental caries in modern populations can be placed into context if that of the past is known (Moore and Corbett, 1971, 1973, 1975; Corbett and Moore, 1976), whilst the work carried out by Møller-Christensen on skeletons excavated from a Medieval leprosy hospital in Denmark furthered understanding of the skeletal changes associated with the clinical signs of leprosy (Møller-Christensen, 1967; Aufderheide and Rodríguez-Martín, 1998).

2.2.1 History and Development.

Long before interest in the study of human remains developed in the late nineteenth century, some attention had been directed towards recording pathological changes in animal bone, but these studies were isolated and did not appreciate the value of the medical data that could be obtained (Aufderheide and Rodríguez-Martín, 1998). As the nineteenth century was a period when most anthropological studies focused on metrical analysis of normal variation, particularly of the cranium, in an attempt to classify populations into different types, little attention was given to pathological lesions in human remains (Walker, 2000; Wells, 1964). In this environment, the study of human palaeopathological changes emerged as a pastime of professionals such as physicians or historians, and was incidental to their main field of study. As such, it consisted of isolated observations, mainly descriptive, of unusual lesions that were of medical interest, (Angel, 1981; Aufderheide and Rodríguez-Martín, 1998). During the first decades of the twentieth century the work of individuals such as Grafton Elliot Smith and Marc Armand Ruffer on Egyptian mummies led to the application of new techniques, and enhanced understanding of palaeopathology within the framework of population-based studies, but unfortunately after the death of Ruffer in 1917 the impetus faltered and the study of human mummies lost momentum (Aufderheide and Rodríguez-Martín, 1998). In the study of skeletal remains, the focus on case studies and the diagnosis of specific diseases continued into the early twentieth century. However, the inherent limitations of the material and unreliability of the diagnoses were not appreciated and little attempt was made at synthesising the data (Angel, 1981; Buikstra and Cook, 1980). The period between the mid-1930s to mid-1960s is generally identified as a period of inactivity and pessimism, with little interest in palaeopathology or interaction between disciplines (Angel, 1981; Buikstra and Cook, 1980). However, Angel (1981) discusses the importance of the work conducted by Earnest Albert Hooton during this period, which advanced the concept of studying populations as a whole rather than individuals.

Interest in palaeopathology was revived in the mid 1960s, encouraged by the publication of major synthetic works, such as that by Brothwell and Sandison (1967). This resurgence has been furthered by the establishment of official organisations (such as the Palaeopathology Association in 1973), the development of specialised courses, and advances in technology (Angel, 1981). Significant progress has been made with the transition to population-based studies, although this has been more evident in work conducted in North America than in the UK (Mays, S. A., 1997), and an increased focus on the interactions between biocultural factors and disease has been evident during the late twentieth century (Lovell, 2000; Roberts, 2000). Recent work has attempted to further this interdisciplinary approach through amassing data from multiple sites to provide information on human health in the past in larger areas of the world, for example the Western Hemisphere Project examining long term trends in health in the Americas (Steckel and Rose, 2002a) and the work by Roberts and Cox (2003) on the history of disease in Britain. The present study seeks to continue in this vein, exploring the possibilities of using pooled data to investigate aspects of health in the past.

2.2.2 Sources of Evidence.

Sources of evidence on ancient disease have been divided into primary and secondary information (Wells, 1964; Manchester, 1987). Secondary sources consist of art (portrayal of disease in paintings, drawings, sculpture, images on pottery and other items of material culture), documentary evidence (contemporary written descriptions of disease in manuscripts, letters, diaries, and literature), and artefacts such as artificial limbs and surgical instruments. Although these are occasionally "direct, detailed and explicit" (Wells, 1964: p23) they must be treated with caution as "under a guise of adroit lucidity they often turn out to be monsters of ambiguity, little better than ink-blot tests which can mean all things to all men" (Wells, 1964: p30). Artistic convention and aesthetic preferences can cause the appearance of a pathological condition where none was intended, or can alter the details of the signs depicted. Even when portrayal of a specific disease was the objective of the artist, several interpretations of the image can often be made (Manchester, 1987; Wells, 1964). Damage suffered by the artwork may also result in misleading impressions of pathological conditions (Wells, 1967a).

Identification and classification of specific disease entities did not occur until relatively recently, and so meaningful evidence derived from historical written sources is largely dependant on interpretation of the signs and symptoms described. These written descriptions of a disease may be unclear, and frequently detail symptoms that could apply to multiple conditions (Wells, 1964). It is also possible that the symptoms now considered to be of utmost diagnostic importance were thought trivial at the time (Roberts and Manchester, 1995). The terminology used can be vague, or may have changed in meaning since the document was written; there may also be issues concerning errors in transcription or translation, and in dealing with damaged and incomplete documents (Wells, 1967a). In all these cases attribution to a specific disease is dubious. In addition, the artist or writer may have focussed on unusual or terrifying diseases, or those that had cultural significance (Roberts and Manchester, 1995), and many diseases, often the most common, may thus have escaped being recorded. Written records are only available for literate societies, so cannot provide information for considerable portions of human prehistory. Despite these limitations, the use of written and artistic sources can provide much useful information, particularly for diseases that do not affect the skeleton, provided they are used with care, and historical data can also provide useful information on the cultural context and living environment of the archaeological populations concerned (Roberts and Manchester, 1995).

Primary sources of evidence for ancient disease encompass all types of human remains, including bones, teeth, and preserved soft tissues. Of these, skeletal material is the most common, being most resistant to degradation, and this is certainly the case in the UK where conditions favourable for mummification are rare; the notable exception being the mummies preserved in peat bogs. Palaeopathology is usually restricted to the study of those conditions that leave some trace on the skeleton, except for infrequent cases where soft tissue has been preserved, although recent methodological developments may allow the diagnosis of soft tissue disease where no skeletal changes are evident, for example the use of mitochondrial DNA to diagnose the presence of tuberculosis bacteria in skeletal remains (Mays, *et al.*, 2002; 2001). However, these techniques are still being developed and are expensive to apply, so most palaeopathological study has to rely on macroscopic examination of the skeletal remains. Unfortunately for palaeopathologists, the vast majority of diseases do not affect the skeleton, and even when a disease is known to do so often only a small percentage of afflicted individuals will develop bone changes. For example, the skeleton will become involved in only 5-7% of individuals suffering from tuberculosis (Aufderheide and Rodríguez-Martín, 1998). Acute soft tissue infections, such as cholera, are resolved too quickly for skeletal involvement – either the individual dies or recovers before the bone can react (Roberts, 2000; Ortner, *et al.*, 1992). Therefore, most palaeopathological evidence is of longstanding, chronic conditions, where the patient survives with the disorder for a reasonable period of time before death or recovery (Roberts, 2000; Roberts and Manchester, 1995). For this reason, palaeopathology cannot normally provide information on the cause of death of the individual or the mortality pattern of a population, but it can reveal considerably more about morbidity, or the occurrence of ill health, at both the individual and population level (Lovell, 2000). The exception might be where unhealed lesions are present, which may have resulted from the disease that caused the death of the individual. However, there is still no guarantee that a person suffering from a serious illness actually died from that illness and not another cause.

The value of human remains lies in the fact that they provide the most direct source of evidence on the disease experiences of past populations, and this is particularly useful where no written or artistic records are available (Roberts and Manchester, 1995; Manchester, 1987). They supply immediate testimony of the human response to their environment, avoiding the subjective problems of interpreting the remains of material culture (Walker, 2000). In addition, they may provide an alternative perspective and a basis for the re-evaluation of such interpretations (Walker, 2000). However, the use of human remains as a source of evidence is subject to various limitations, which are discussed in full below. Therefore, the use of diverse sources of evidence, combining biological with cultural and environmental data, is to be encouraged in order to develop the most comprehensive and balanced understanding of the past possible.

2.2.3 Methods of Investigation.

There are a variety of ways through which information can be gathered from human remains (Lovell, 2000; Mays, 1998). The most basic is macroscopic observation, which requires that the observer be trained in human osteology and is able to notice and describe pathological changes (Lovell, 2000; Miller, *et al.*, 1996). Simple visual inspection is often supplemented through the use of radiography, essential in allowing the observation of changes that might otherwise have remained hidden, such as the early stages of many neoplastic diseases, and augmenting the information recorded on conditions such as fractures (Mays, 1998; Wells, 1964). An endoscope can prove useful when the area of interest is enclosed and would be difficult, or impossible, to view otherwise, such as investigations into the prevalence of maxillary sinusitis in intact crania (Roberts, *et al.*, 1998). Microscopic analysis can be used to "clarify, confirm, or refute the nature of lesions that have been identified macroscopically" through studying the lesion at the cellular level (Lovell, 2000: p225). The use of biochemical methods has recently become more frequent, and techniques such as the analysis of trace elements and stable isotopes have been applied to the problems of dietary reconstruction (Lovell, 2000). In North America this approach has been used to investigate the effect that the transition to (or intensification of) maize agriculture had on the health of the Native American populations, particularly the prevalence of dental caries (for example, Hutchinson, *et al.*, 1998; Larsen, *et al.*, 1992). It can also be used to determine the amount of marine foods present in the diet (Mays, Simon A., 1997; Privat and O'Connell, 2002; Chisholm, *et al.*, 1983), a fact which may be of interest given the relationship between marine fish and dental caries (discussed in Section 3.3.4.1.3). Developments in the recovery and analysis of ancient DNA and immunoglobulins mean it is now possible to discover evidence of the pathogens themselves (for example, the retrieval of *Mycobacterium tuberculosis* DNA from archaeological human remains (Mays, *et al.*, 2002; 2001)) or the biological response to the presence of the pathogen (Lovell, 2000; Ortner, *et al.*, 1992). The study of ancient DNA has the potential to investigate diseases that do not affect the skeleton, and to enhance understanding of those that do. In addition, it may enable research into the occurrence of genetic diseases in the past (Lovell, 2000; Ortner, *et al.*, 1992). The limitations of the methodology used will affect the quality of the data collected and the research conducted, and it is important that these are acknowledged and addressed.

2.2.4 Clinical Basis for Diagnosis.

Knowledge of the changes that occur in clinical cases of a disease forms the basis for diagnosis of disease in skeletal material, although there are problems with this approach (Ortner, 1991; Roberts, 2000). Clinical diagnosis is commonly established from the patient's symptoms and history, combined with medical tests, and even then diagnosis can prove difficult (Miller, *et al.*, 1996; Ortner, 1991; Waldron, 1994a). Patients will only approach a doctor when they have symptoms, and as a result there may be little knowledge of the early stages of a disease (Miller, *et al.*, 1996). There are few skeletal collections where medical records are associated with individuals, and so much information is obtained from radiographs of living patients. Because only a limited area of the body is radiographed, changes occurring in non-radiographed areas will pass unnoticed. Subtle lesions may be overlooked, as a 40% change in bone density is required before pathological changes are discernable (Ortner, 1991), and unfortunately minor lesions are then excluded from the diagnostic criteria used in palaeopathology.

Information on the bone changes associated with disease is also limited because of the effectiveness of modern medical treatment; as with surgical and therapeutic intervention few diseases progress to the extremes that would have occurred in the past (Miller, *et al.*, 1996; Buikstra and Cook, 1980). For this reason "palaeoepidemiologic models should emphasise studies that predate effective therapy, yet are recent enough to reflect accurate diagnosis" (Buikstra and Cook, 1980: p441).

This situation is complicated further by the fact that past diseases may no longer exist, new diseases may have emerged, and current diseases may have evolved to the point where they cause different pathological changes to those they caused in the past (Miller, *et al.*, 1996; Ortner, 1991). Not all cases of a disease will conform to the expected pattern of changes, and indeed a particular disease may be expressed in a variety of ways, which can vary with the age or sex of the individual and the stage of the disease process. This should be borne in mind when dealing with archaeological skeletons, as the person could have died during any phase of a disease (Ortner, 1994).

2.2.5 Description, Classification and Differential Diagnosis.

As bone is a living tissue it is capable of responding to disease, but the ways in which it can do this are limited. New bone can be formed (blastic/proliferative response), bone can be destroyed (lytic/resorptive response), or a combination of both processes can occur simultaneously (Roberts and Manchester, 1995). Due to the restricted nature of bone response, several diseases may result in bone lesions of a similar appearance and it can be difficult, if not impossible, to distinguish between lesions caused by different diseases (Ortner, *et al.*, 1992). For this reason, careful, detailed observation and description of the type of bone changes present, as well as their location on the bone element and distribution throughout the skeleton, is fundamental and provides the basis for classification (Ortner, 1994, 1991; Buikstra and Cook, 1980; Roberts, 2000). Usually several feasible causes for the changes observed should be suggested and discussed – the process of differential diagnosis, which is based on what is known from clinical studies of how different diseases affect the skeleton. The process of classification is complicated by the possibility that the individual concerned was suffering from more than one condition simultaneously (Buikstra and Cook, 1980). It is also important to recognise pseudopathological lesions, i.e. changes caused by mechanical forces, chemical erosion, the action of living creatures on the buried skeleton and excavation/post-excavation damage to bones and teeth which could be mistaken for pathological conditions (Wells, 1967a).

Research in palaeopathology is based on the diagnosis of disease from skeletal remains, so accurate classification of pathological lesions is vital. Without a reliable diagnosis, further investigation becomes meaningless (Ortner, 1991). Miller *et al* (1996) demonstrated that the ability to diagnose pathological changes correctly was largely dependent on the knowledge and experience of the observer, and that common conditions were more easily recognised than those that occurred less frequently. They concluded that it was better to assign the pathological changes to a general disease category, rather than attempt a specific diagnosis. For these reasons it is important that a thorough description of the changes observed is supplied, and that the diagnosis does not become the description. Under these circumstances the diagnosis provided can be re-evaluated by the reader.

It is therefore essential that palaeopathologists have been trained to record data from skeletal remains to a consistent and common standard (Roberts, 2000). The existence of degree courses at Masters level has ensured that practical training in the recording of skeletal remains to a high standard is available, combined with teaching on the theoretical issues relating to the study of palaeopathology. Publications are available to provide guidelines on what should be recorded and how. Until recently the main reference source was that prepared for the collection of data from skeletal remains in North America, edited by Buikstra and Ubelaker (1994), but guidelines addressing British requirements have just been published (Brickley and McKinley, 2004). Specific recording issues have been addressed in other publications that have sought to create standards for the recording of pathological lesions, for example cribra orbitalia (Stuart-Macadam, 1991), or that have defined criteria for the differential diagnosis of a disease, such as Diffuse Idiopathic Skeletal Hyperostosis from ankylosing spondilitis (Rogers, *et al.*, 1981). In addition, organisations such as the British Association of Biological Anthropology (founded in 1999) and the Palaeopathology Association exist to encourage and develop high standards in research.

2.2.6 Palaeoepidemiology.

Lovell (2000: p238) defines palaeoepidemiology as "the term used when referring to the study of patterns of trauma or disease in which the population, rather than the individual, is the unit of analysis". Assuming that the sample size is large, the data collected from each skeleton is amalgamated to obtain information on the population as a whole. The relationship between different pathological conditions and demographic or cultural factors (such as age, sex, occupation, social status) can then be examined, and valuable information obtained on the history and development of various diseases (Lovell, 2000). In order to do this, an indication of the frequency with which a disease occurs is required. The use of incidence (the number of new cases of a disease that occur in the population at risk within a defined period of time) is impossible to assess in palaeopathology as the time period is often unknown, and the 'at-risk' population and number of new cases occurring cannot be determined (Waldron, 1991, 1994a). Prevalence, or "the proportion of the population with a specified condition at any one time" (Waldron, 1994a: p42), is more appropriate as it is applied to a cross-section of the population.

Although necessary for analysis, simply providing information on the number of individuals affected by a disease can be misleading when the skeletons are incomplete or damaged, which is usually the case in palaeopathology; if a condition affects a certain part of the skeleton and that part is missing as a result of postmortem damage in several individuals then it is impossible to determine whether or not those individuals were affected. In these circumstances individual prevalence rates may underestimate the true prevalence rate of the condition. For this reason bone prevalence rates, given as the number of bone elements affected as a proportion of bone (or teeth) elements present, are also employed, and this measure is useful for comparisons between populations (Roberts, 2000; Waldron, 1991). The prevalence of a condition can be affected by factors such as age and sex, so it is more appropriate to compare age- or sex-specific prevalence rates if possible, the problem with this approach being that it is impossible to know at what age the person acquired the disease.

2.2.7 The Osteological Paradox
"Near deid never filled the kirkyaird" (Firth, 1974).

Translating the prevalence of a condition in a skeletal population into meaningful information on the actual prevalence of that condition in the living population can be problematic. Waldron (1991) demonstrates that prevalence rates can be a reasonable approximation for diseases that do not shorten lifespan, but not for those that do. However, due to the nature of the skeletal response to disease, where acute conditions may result in death before bone changes can occur, it may be impossible to distinguish between an unhealthy and a healthy population from the skeletal assemblage; it is possible that apparently healthy skeletons showing no evidence of pathology could equally well be the remains of unhealthy individuals whose immune systems were incapable of coping with the severe stress of acute disease as neither set of skeletons will display evidence of ill health. However, in a moderately healthy population, where the majority of individuals have a reasonably good immune response, most will survive the acute stages of a disease to develop chronic, healed lesions, yet this population will appear less healthy than both the healthy and unhealthy populations described above (Wood, *et al.*, 1992; Ortner, 1994, 1991). Paradoxically, the presence of healed lesions can therefore be interpreted as evidence of a good immune response (Wood, *et al.*, 1992; Roberts, 2000).

A fundamental problem, intrinsic to the nature of the material, is that a skeletal sample consists of dead individuals (i.e. those most likely to die at each age) and there is no information on those individuals in each age group who survived (Wood, *et al.*, 1992). Therefore, the frequency of disease in the original living population will be lower than that observed in the non-survivors (the skeletal sample) as it is presumed that those who died were more likely to have suffered from disease. Conversely, the prevalence of a condition in the skeletal sample may under-represent that of the original population due to the fact that bone changes may not occur in response to a disease, may not be diagnosed, or be more likely to suffer from poor preservation than normal bone. Without information on the fertility of the population and the number of people migrating into, or away from, the group it is difficult to reconstruct the demography of the living population (Wood, *et al.*, 1992; Waldron, 1994a). For these reasons, a skeletal sample can never truly represent the original living population.

2.2.8 The Nature of the Sample.

Human skeletal remains used in palaeopathological studies have usually been excavated from archaeological sites, and are therefore subject to the limitations inherent to all archaeological material. The assumption often made is that the skeletal sample represents the original population from which it was drawn. However, there are numerous factors that affect the composition of the sample analysed by the osteologist. Cultural behaviour governs the method of disposal of the corpse, which may not necessarily involve burial (Metcalf and Huntington, 1991). Recent European Christian populations have tended to favour internment of bodies within defined churchyards, a practice that makes archaeological discovery and recovery of skeletal material more likely. However, earlier non-Christian populations may have had a variety of funerary customs, including cremation and excarnation, which can reduce the likelihood of survival of human remains and the amount of information that it is possible to retrieve from them. Cultural factors may also determine who is buried and where: certain members of society may be given differing burial rites or even excluded from normal burial (Waldron, 1994a). Children may be excluded from burial in the normal cemetery, for example unbaptised infants in the Late Medieval period, and individuals with leprosy were segregated from society and buried in a separate cemetery (Daniell, 1997).

Only a section of the original living population would have been buried in a particular cemetery, and not all of those buried will survive to be excavated (Waldron, 1994a). Different soil types, pH levels, temperature, the amount of water present, depth of burial and other factors will all influence the preservation of human bone (Garland and Janaway, 1989; Henderson, 1987; Janaway, 1996). Poor preservation can reduce the quality of information available from human remains, and make bone more vulnerable to damage during excavation and post-excavation processing. It can make it difficult to determine the age or sex of the individual, or impossible to identify pathological changes. Some bones, including small, fragile or pathological elements, or skeletons of individuals of a particular age or sex may be more vulnerable than others to decay in certain conditions (Walker, 1995). Incomplete skeletons cause problems when recording pathological conditions, as the distribution of lesions is crucial for differential diagnosis. For example, the common under-representation of small bone elements from the hands and feet can impair the diagnosis of conditions such as leprosy or rheumatoid arthritis (Waldron, 1987b). In addition, partial skeletons cause problems when calculating the frequency of individuals with a given pathology, which causes difficulties when comparing disease prevalence between sites.

It is likely that the original cemetery will not be excavated in its entirety, especially in an urban context, and if individuals are buried in different locations according to age or sex then this may prejudice the sample retrieved (Waldron, 1994a). Bone elements may also be lost or damaged during excavation, post-excavation processing, curation and analysis (Spriggs, 1989; Stroud, 1989; Caffell, *et al.*, 2001). The skeletal material available for study by the osteologist is therefore but a small, and possibly biased, sample of the original population from which it was drawn. An additional complication with archaeologically excavated cemeteries is that they were often in use for a long time, and so the human remains recovered are not a cross-section of the population at any one moment but reflect an accumulation of burials over a period of centuries.

2.3 Medical Geography.

2.3.1 The History of Medical Geography in Europe.

Disease has always had an impact on the lives of people, both at the level of the individual and of society as a whole. Everyone suffers from illness at some stage in their lives, whether this is temporary or permanent, acute or chronic. In consequence the health of the population is very relevant to social, economic and political developments: disease can reduce the economic productivity of a population, instigate political and social change, and even influence the outcome of wars (Porter, 1999). A well-known example of the impact a disease can have on a population is the repercussions of the plague in Late Medieval England (Gottfried, 1978; McNeill, 1994). It is unsurprising that throughout history attempts have been made to rationalise and understand the occurrence of disease, and to arrive at an explanation for its cause. The naturalistic philosophy of Ancient Greece came to dominate Western medicine until the advent of bacteriology in the mid-nineteenth century, which seemingly refuted the belief in wider environmental causes of disease. It was not until after the Second World War, with the increase in chronic and degenerative diseases, that the focus shifted once again to environmental influences on health (Hannaway, 1993). Medical geography, defined as "the comparative study of the spatial distribution of diseases and their possible causes" (Howe, 1997: p1), has been widely used to offer insights into disease causation in the last half of the twentieth century (Verhasselt, 1993; Westlake, 1995; Lloyd, 1995; Mayer, 2000). However, in order to appreciate why medical geography developed, its origins have been considered.

2.3.2 Airs, Waters and Places: An Early Medical Geography.

The origins of medical geography can be found in Classical Greece, where naturalistic views on health and medicine focused on the relationship between the environment and wellbeing. It is probable that the structure of Greek society, which included urban centres, made intellectual theorizing on the nature and cause of disease possible. Urban centres, being in trading contact with other groups and having larger, and possibly less healthy populations, encourage specialization and debate. This is in contrast to rural societies where much of the population probably relied on traditional remedies and practical self-treatment (Nutton, 1995d). Despite philosophic debates about the nature of the body resulting in several different theories on its exact composition (Nutton, 1995c), the body was generally believed to consist of four humours in balance with the environment, and illness resulted when this balance was disturbed (Nutton, 1993). Humoral composition could vary according to the seasons or other environmental factors; it could also change throughout life and was different in different people. Disease was therefore an individual experience and treatment, based on altering the lifestyle and diet to repair the humoral balance, was tailored to each person (Nutton, 1993; Lonie, 1977). Preservation of health was considered to be more important than curative medicine, and was achieved through maintaining a regulated lifestyle appropriate to the environment and the humoral composition of the individual concerned.

Understanding environmental influences was therefore crucial in understanding and managing disease. Travelling healers would have used their knowledge of places and their environments to anticipate what diseases they would find in each new town or village and to help them prescribe the necessary regimen (Nutton, 1995c; Wilkinson, 1993). Discussions of different places, their respective environments and associated diseases form the subject of *On Airs, Waters and Places*, one of the 60 texts of the Hippocratic Corpus written between 420 and 370BC (Nutton, 1995c). Rosen describes this text as "the first known systematic endeavor to present the causal relations between environmental factors and disease" (Rosen, 1993: p9), and as such it can be viewed as an early medical geography. Not only does it discuss the factors influencing endemic and epidemic disease, it describes the ideal types of location for building healthy towns (Rosen, 1993). Avoidance of miasma (bad air) was seen as an important preventive against epidemics, and therefore locating buildings and towns away from potential sources of miasma was advisable (Nutton, 1995c, 1983). A thorough knowledge of topography and climate was therefore essential to both prevent disease and cure it when it occurred. These ideas expressed in the Hippocratic Corpus were reiterated and modified by Galen (c. AD 129 - c. AD 216), thus creating a theoretical framework that had a profound influence on the subsequent development of medicine and which persisted until the mid-nineteenth century (Nutton, 1995d).

2.3.3 Religion and Medicine.

The decline of urban centres and increasing fragility of institutions followed the disintegration of the Western Roman Empire, and this had a profound impact on medical theory and practice (Nutton, 1995a; Rosen, 1993). With the loss of the urban centres that had enabled medical debate, and the rarity of increasingly expensive books, there was little opportunity to develop theories and experiment with new ideas and techniques. As the authority of the Christian Church increased from the fifth century onwards, monasteries became the centres of learning and almost all aspects of life became subject to religion (Nutton, 1995a). The belief in the eternal soul placed the utmost importance on saving the soul from an eternity in hell, and the "more the body appeared a temporary habitation of an immortal soul, the less the need to attend to it" (Nutton, 1995a : p77). Contamination or corruption of the soul due to sins committed by the body resulted in punishment through physical disease. Healing was thus closely connected to religion, with confession, repentance and penitence being important measures for correcting sin and so contributing towards the physical cure. A cure could also be effected through divine intervention in the form of a miracle (Nutton, 1995a; Daniell, 1997).

Although the Church never rejected secular medicine, the ideal of trial by suffering and mortification of the flesh did not relate easily to the Hippocratic principle of balance and moderation (Nutton, 1995a). Supernatural and divine causes of disease took precedence over environmental causes, and so there was no longer a need to understand the influence of the natural environment or to investigate its relationship with health. However, an awareness of the effect of unhealthy environments is apparent in their association with fearsome beasts, which were widely believed to cause disease: for example, it was believed that the diseases found in and around swamps and marshes were caused by air contaminated by the breath of the dragons residing there (Horden, 1992). The personification of diseases in these monsters may have made the abstract danger from disease more tangible and understandable, and explained on a supernatural level why certain environments were more dangerous than others. Fear of the monsters would have discouraged people from inhabiting, cultivating or travelling through these dangerous areas, and so would have helped prevent cases of disease (Horden, 1992). It is notable that the monsters are often vanquished through the intervention of religious men, usually saints, and so the control of religion over disease is maintained.

2.3.4 The Renaissance.

Despite the influence of the Church during the Early Medieval period, the concept of humoral balance with the environment as expressed in the ideas of Galen and Hippocrates was retained. This concept flourished with the increased power of secular government and the development of towns and universities as centres of learning during the twelfth and thirteenth centuries (Nutton, 1995b). Although God remained the primary cause of disease, natural causes in the weather, seasons and astronomy were also sought, the latter becoming of increasing importance during the Renaissance (Hannaway, 1993). Miasmas resulting from decomposing matter, stagnant water, waste material, and caves were considered to be important in disease causation, as was the concept of contagion (Pelling, 1993; Cipolla, 1992; Hannaway, 1993). The humours of the body were influenced by the 'six non-naturals' – another name for the aspects of lifestyle that could be controlled by the individual. These included food and drink, sleep and waking, air, evacuation and repletion, movement and rest, and the passions/emotions (Nutton, 1995b; Wear, 1995). The complex interrelationships between this multitude of varied ideas are discussed by Pelling (1993) and also by Pullan (1992) with reference to Italy. As before, health was controlled through regulations of diet and lifestyle, with religious measures required to mitigate divine causes of ill health.

The explosion of interest in science and experimentation in the sixteenth century led to the development of new equipment allowing quantifiable measurements, such as the thermometer (Hannaway, 1993; Wear, 1995). Encouraged by the political need to investigate local resources this stimulated the exploration of the physical properties of the environment, and increasingly allowed the possibility of their correlation with disease (Valencius, 2000). Thomas Sydenham developed the latter idea during the seventeenth century with the aim of providing better treatment for his patients (Hannaway, 1993; Rosen, 1993). These ideas were to be expanded during the eighteenth century, as the environment became an increasingly important factor in health.

The inquisitiveness characteristic of the Renaissance also promoted an increase in knowledge about the human body through the development of anatomy. Although the first human dissection had taken place around 1315 in Bologna, dissections of human corpses did not become a widely accepted part of university medical teaching until the sixteenth century (Nutton, 1995b). Prior to that, animals were dissected and the findings translated to the human body, which was perfectly compatible with the Aristotelian scientific framework and belief in the unity of creation (Nutton, 1995b). The establishment of human anatomy was encouraged by the artistic interest in the naturalistic portrayal of the human body in the fifteenth century, and many artists, including Leonardo da Vinci, routinely studied dissected corpses to increase their anatomical knowledge and to improve their art (Wear, 1995). In addition, Galen had recommended daily dissection and the renewed interest in his work led many to follow his example. Anatomical drawings became increasingly important in anatomy texts from 1520 onwards.

2.3.5 The Development of Thematic Maps.

An important development in the study of the relationship between disease and the environment, and the causes of different diseases, was the development of thematic maps. Thematic maps display "the geographical character of a great variety of physical, social and economic phenomena" (Robinson, 1982: p ix), and are used to search for, and examine, the reasons for any patterns that may emerge in their distribution. A necessary prerequisite was the development of adequate topographic maps, showing the geography of the landscape with sufficient accuracy and detail to provide a base map for the plotting of other data. These had become common during the European Renaissance following an increase in mapmaking, and their availability was enhanced through mass production as a result of the developing printing techniques (Harvey, P.D.A., 1993; Harvey, 1987). An additional requirement for thematic maps was the ability to record quantifiable measurements about the phenomena under investigation, and these skills emerged during the sixteenth century. Therefore, thematic maps appeared towards the end of the seventeenth century as a result of an increased intellectual curiosity about natural phenomena and the behaviour of people, enabled by the technological and theoretical developments of the

Renaissance. They provided a means for people to investigate, understand and portray many aspects of the physical and social world. Early thematic maps were focused on analysing the physical environment, reflecting the concurrent interests and developments in science, and portrayed distribution information on such subjects as the weather, ocean currents, geology, vegetation and animal life (Robinson, 1982). The techniques were later applied to explore questions related to other disciplines, including medicine.

2.3.6 Environmental Medicine.

Jordanova (1979) has discussed the synthesis of the earth sciences and environmental medicine during the eighteenth and early nineteenth centuries in detail. During this period the prevailing enthusiasm for experimental science, and general interest in the natural world, fostered the revival of Hippocratic ideas in the intrinsic links between health and place (Hannaway, 1993; Rosen, 1993). This renewed focus on the environment was combined with fact collecting, an avoidance of supernatural explanations for natural phenomena, and attempts to describe and categorise diseases (Jordanova, 1979). This led to the writing of medical topographies, which involved intricate descriptions of the environment of a restricted area in order to investigate its links with the health of the local population (Hannaway, 1993; Harrison, 2000). Certain places, such as the spa towns and seaside resorts, became associated with health and evolved into fashionable centres of healing and pleasure (Gesler, 1998; Coley, 1979). This local geographical awareness was enhanced by the European colonisation of new lands, and the necessity of learning how to preserve the health of settlers and the military and cure unfamiliar diseases in exotic climates (Harrison, 2000; Hannaway, 1993; Pickstone, 1992). Later the geographical scope of these medical topographies was expanded to discuss larger regions, countries or even the known world, and they became known as medical geographies. Understanding the environment led to the possibility of human control and so undesirable features could be altered, for example marshes could be drained (Jordanova, 1979; Valencius, 2000).

James Lind (1716-1794) is best known for his contributions to the understanding and prevention of scurvy, but he also contributed to the beginnings of medical geography (Barrett, 1991). His work has a strong geographic focus, being an analysis of the links between diseases and locations in an attempt to understand why certain diseases occur in some places but not others. His suggested remedy for ill health involved a change of location – a geographical solution to a medical problem (Barrett, 1991). This work was to influence Leonhard Ludwig Finke (1747-1837), credited as "the first to deal directly with the fundamental conceptual issues of the nature and scope of medical geography" (Barrett, 1993: p708). Inspired by Hippocrates, Finke used geography to link cause and effect, offering insights to disease from a geographical perspective. The intention was to provide a reference work of practical use to physicians in diagnosing and treating ill health (Barrett, 1993; Rosen, 1953). Neither Lind nor Finke included maps in their published works, although Barrett (2000) discusses the evidence that Finke produced a world disease map in 1792. From the available evidence Barrett hypothesises that this was probably a textual map, with the names of the diseases written in their locations. This is the first stage of disease map development discussed by Rupke and Wonders (2000). However, as it was never published it had little impact on medical geography or medical cartography.

The preoccupation with medical geography remained dominant until the advent of bacteriology in the last half of the nineteenth century (Rupke, 1996). Due to the rapid population growth and social upheavals of the industrial revolution conditions in the rapidly expanding towns and cities deteriorated, and there was a growing concern amongst the upper and middle classes with the economic costs of the increased morbidity and mortality amongst the poor and labouring classes (Pelling, 1993; Robinson, 1982). However, the factors causing disease were much in debate, with a complex relationship between theories of contagion and anticontagionist theories, which held that disease arose from sources of putrefaction in the local environment, and the theoretical middle ground (Pelling, 1993, 1978). Public health strategies were developed in response to the perceived environmental causes, both natural and social, and to be effective these required knowledge of the spatial distribution of disease as well as adequate social statistics (Pickstone, 1992). The belief in the importance of the study of the disease location in order to find the cause is illustrated by the work of contemporaries such as Thomas Shapter (1809-1902) and James Clark (1788-1870). As well as including a detailed description of the city of Exeter (including its location, water supply, waste-disposal, sewerage systems and the conditions of the poor), Shapter (1971) includes a map of the cases of cholera in Exeter between 1832-4, associating areas of high mortality with poverty and poor drainage. Clark (1841) provides comprehensive descriptions of diseases and their associated climates, prescribing travel to places with the appropriate climate as a cure for the disease in question.

2.3.7 Medical Cartography.

The development of disease maps during the nineteenth century reveals the importance of spatial thinking in medicine at the time:

> "Maps suggestively connected the causes of diseases with their geographic occurrence, and gave considerable weight to views of environmental determinism in thinking about health and disease" (Rupke and Wonders, 2000: p163).

Thematic maps showing disease distributions began to appear in the last decade of the eighteenth century. These early disease maps arose in response to the yellow fever epidemics in North America, and were used to examine the origin and spread of the disease as well as to illustrate links between the disease and factors believed to influence its occurrence (Stevenson, 1965). Attempts were made to relate concentrations of yellow fever cases displayed on the map to local environmental conditions believed to be sources of putrefaction (Stevenson, 1965). Therefore, the primary use of these maps was illustrative, rather than analytical, and the map was of secondary importance to the written report.

The number of disease maps rose sharply during the nineteenth century, and it is widely accepted that this was related to the social impact of the cholera pandemics of the time (Gilbert, 1958; Jarcho, 1970; Robinson, 1982). Without an identifiable cause of the disease it was impossible for the authorities to take action to prevent or control an epidemic, and so discovering these causes was paramount (Camerini, 2000). As with yellow fever the cholera maps were intended to display the distribution of cholera "in the hope of identifying environmental factors which might influence the progress and severity of the disease" (Robinson, 1982: p40). As cholera tended to be located in the low-lying areas near rivers this was believed to support a link between elevation, meteorology, miasma and cholera (Gilbert, 1958; Cliff and Haggett, 1988). This was a connection made by August Petermann when he drew his 1848 shaded cholera map of Britain to indicate the geographical variations in the density of the disease. Later, following his creation of population density maps, he realized that it was the population density of an area, not its elevation, which was more important in determining the disease density (Camerini, 2000).

John Snow is often hailed as a pioneer in medical geography, and his 1854 cholera map (Frost, 1965) has been described as a breakthrough in disease mapping (Cliff and Haggett, 1988). The story is well known: during the outbreak of cholera in the Golden Square district of Soho in 1854 John Snow plotted the cases on a map, realised that the outbreak was concentrated around the Broad Street pump, and inferred that its contaminated water was the source of the epidemic. On removal of the pump handle the number of new cases of cholera dropped dramatically, and the epidemic was halted (Cliff and Haggett, 1988; Robinson, 1982). Snow also investigated the incidence of cholera in London with reference to the water-supplier, finding that those areas supplied with water from contaminated sources had a much higher incidence of cholera (Frost, 1965). Again these results are displayed in maps, visually highlighting the connection between the two. Snow arrived at what we now perceive to be the 'right' answer, which might explain the degree of attention given to his work in the medical geography literature compared to other early investigators, who used cholera maps in support of miasmatic theory.

2.3.8 The Microbiological Revolution.

The belief in environmental causes of disease was overthrown with the discovery of the role of bacteria in disease causation in the 1880s. Although various theories had postulated that micro-organisms were responsible for disease (Howard-Jones, 1977), it was not until the work of Louis Pasteur (1822-1896), Robert Koch (1843-1910), and their associates, that the relationship was proved and germ theory developed (Pelling, 1993). Rapid identification and association of micro-organisms with diseases during the 1880s and 1890s led to the assumption that single factors were responsible for specific diseases, for which specific cures were sought. Diseases were now identified as entities in their own right, with consistent effects in different patients. Safe vaccines and antibiotics were developed by the 1930s and 1940s providing a means of disease control, and the new scientific approach became associated with improved diagnosis and better treatment from the perspective of the general public (Porter, 1999). However, the effectiveness of the new treatment can be questioned: although the decline of tuberculosis in the early twentieth century was claimed to be due to the advances of medical science, it is likely that an improvement in living conditions was the real cause, as the decline had begun long before effective antibiotics were developed (Davies, *et al.*, 1999). The ontological view of disease also led to the marginalisation of the patient in medical care; science distanced the laboratory from medical practice and doctors treated the disease not the patient (Pelling, 1993; Porter, 1999). With the causes of disease safely discovered, there seemed to be little purpose in investigating the environment for possible causative factors and the importance of medical geography declined. The role of the environment in germ theory was constricted to being the source of the disease-causing pathogens (Valencius, 2000). However, despite this shift away from medical geography and environmental influence, place and environment remained important in the treatment of some diseases during the early twentieth century, for example the removal of tuberculous patients to sanatoria located in places deemed to have a healthy environment (Numbers, 2000).

2.3.9 Rediscovering the Environment.

Following the end of the Second World War, with infectious diseases apparently under control in the developed world, attention once again returned to the role of the environment in disease causation. Reduced morbidity and mortality from infectious diseases, longer life expectancies and improved standards of living meant that the prevalence of chronic and degenerative diseases, such as heart disease and cancer, increased (Pelling, 1993). With no specific micro-organisms to target as the cause, the importance of exploring multifactoral environmental influences on health became apparent. Concerning diseases of known aetiology, it was realised that "diseases do not develop in a vacuum" (Cipolla, 1992: p76); i.e. that the influence of environmental factors on pathogens and human behaviour could affect the dynamics of infectious diseases (Wilkinson, 1993; Roundy, *et al.*, 1983). The influential paper by Jacques May (1950) highlighted the value of applying geographical techniques to the problem of understanding disease. He discussed biological pathogens and the geographical factors that may influence them, including climate, soil, food, water, and human culture. His paper reinstated medical geography as an important research method that can make valid contributions towards the understanding of disease, and through defining its research questions he provided the foundation and inspiration for later work (Thomas, 1990, 1992; Valencius, 2000).

2.3.10 Current Medical Geography.

Since the revival of medical geography in the 1950s and 1960s the discipline has grown rapidly in response to the new focus on the environment and health, greatly facilitated by the development of computers. Broadly defined by Meade and Earickson (2000: p1) medical geography "uses the concepts and techniques of the discipline of geography to investigate health-related topics". This includes the traditional analysis of spatial variations in human health and disease and their attempted correlation with potential social and environmental causes, which was the main focus of work in the 1950s and 1960s (Howe and Phillips, 1983), for example studies carried out by Dunn *et al.* (1995; Dunn and Kingham, 1996a, 1996b) have investigated the link between atmospheric pollutants from a factory and respiratory disease in a nearby town in County Durham. Studies of aggregate data can explore general disease patterns, and can be used to suggest new hypotheses for the more detailed analysis of specific aetiological factors (Douven and Scholten, 1995; Giles, 1983; Lloyd, 1995). Medical geography also encompasses the relatively recent development of the study of health-care provision (Meade and Earickson, 2000; Eyles and Woods, 1983), which is concerned with the distribution of resources, and other factors that may influence the delivery, accessibility and utilisation of health-care (Stern, 1995; Bain, 1983; Lee, *et al.*, 1998; Takahashi, 1998).

It is a concern that the biomedical focus on the disease-causing organism excludes the experiences of the patient and the influence of the environment from the understanding of the disease. Despite the fact that "the century-long primacy of the micro-organism in thinking about disease causation is being eroded" (Hannaway, 1993: p292), the ideas of bacteriology persist in the ideas of Western science and popular culture, where disease is presented as having single-factor causes and specific cures (Pelling, 1993). Recently, the importance of considering the social context of disease in medical geography has been discussed, and it has been suggested that insufficient attention has been given to social, cultural, economic and political factors affecting disease (Asthana, 1998; Kearns and Gesler, 1998; Kearns and Joseph, 1993). Whilst it is important to remember that the human context gives meaning to disease (Slack, 1992), and that it can be argued that disease is a human construct (Jones and Moon, 1987), its biological basis must not be denied (Brieger, 1993). As Jones and Moon have stated: "Diseases must not be seen as exclusively social or biological phenomena for they are simultaneously both" (Jones and Moon, 1987: p7).

There has been a tendency in past palaeopathological studies to focus on the disease at the expense of the patient. The discussion above has highlighted the importance of considering both biological and social factors when examining the evidence from skeletal remains, and therefore this approach has formed the basis for interpreting the data in the current research.

3 DENTAL CARIES

3.1 Introduction.

Dental caries is an infectious disease, defined as "the localized destruction of the tissues of the tooth by acids, particularly lactic acid, produced by the fermentation of dietary carbohydrates by bacteria in dental plaque" (Marsh, 1999: p599). Due to this destruction of tooth tissue, the individual suffers symptoms of pain and sensitivity to temperature in the affected tooth, and may experience difficulties in mastication. If the lesion progresses, it can eventually lead to the development of an abscess in the pulp cavity and, potentially, to loss of the tooth (Zero, 1999; Moynihan, 2003). Multiple factors can influence the formation and progression of carious lesions, including genetic, behavioural, dietary and chemical factors, and these are discussed below. There are geographic variations in the modern prevalence of caries, with high levels found in Western industrialised countries and low levels in developing countries. Within each of these countries regional variations in caries prevalence can often be found (Elderton, 1990). These differences are primarily attributed to variations in diet, availability of fluoride, health education, oral hygiene and access to adequate dental care.

3.2 Caries Development.

The presence of bacteria is essential for the development of carious lesions: a series of animal experiments in the 1950s demonstrated that caries did not occur in bacteria-free animals, even if they were fed a cariogenic diet high in sugars (Marsh, 1999). The mouth is colonised during infancy by oral bacteria transmitted from the parents (usually the mother), and an established community of bacteria is soon formed. Of these, *Streptococcus mutans* has been identified as the most cariogenic (Edgar, 1990a; Gripp and Schlagenhauf, 2002). The bacteria are found massed together in dental plaque, which is defined by Edgar (Edgar, 1990a: p87) as "a dense, organized deposit of bacteria within a matrix derived from salivary proteins, which usually include bacterial polysaccharide products". Plaque accumulates on the teeth, separated from the enamel surface by a thin layer of bacteria-free, organic film called the pellicle, which may help protect the enamel (Zero, 1999). As thicker layers of plaque collect in stagnant recesses, pits and fissures, such as on the occlusal surfaces of the molars, between malaligned or overlapping teeth, or in irregularities in the smooth surface enamel, these are the areas most prone to dental caries (Zero, 1999).

Under normal conditions the pH of the plaque is neutral (c. pH 7); it is only when the oral bacteria metabolise carbohydrates, particularly sugars, and produce acid that the pH level drops. The critical pH level, below which the tooth is vulnerable to developing caries, is pH 5.5, and the pH level can remain low for as long as an hour after eating (Zero, 1999). The acid generated by the bacteria demineralises the enamel, a process by which mineral components of the enamel diffuse out of the tooth. When the pH rises, remineralisation can occur, and the tooth structure incorporates minerals from the surroundings. There is an ongoing cycle of demineralisation and remineralisation, and caries occurs when the balance is in favour of demineralisation; overall more minerals are lost from the tooth than are regained. If this situation is maintained then the carious lesion remains active and continues to destroy the tooth tissue. However, if at any stage the demineralisation/remineralisation balance is re-established then the lesion will be arrested. It is even possible for early carious lesions to be reversed if remineralisation prevails (Zero, 1999; Silverstone, 1990). This is the only repair method available to enamel, as it is incapable of any cellular repair or defence mechanisms.

The first clinical appearance of a carious lesion is a white spot of demineralised enamel. As the lesion progresses a cavity forms in the enamel, which is not repairable although it may become arrested. The dentine experiences demineralisation before the appearance of a cavity in the enamel, and considerable damage can be done beneath an apparently small enamel lesion. Unlike enamel, dentine is capable of cellular defence, and will form layers of secondary dentine to protect the pulp chamber. Bacteria invade the dentine following the formation of a cavity in the enamel, expediting the progress of the lesion. Eventually, the underlying tissue may become so damaged that the unsupported enamel surface collapses and a large cavity is formed. Inflammation of the pulp tissue leads to the generation of pus and abscess formation, and possibly necrosis and tooth loss (Silverstone, 1990).

3.3 Factors Influencing Caries Development.

3.3.1 Host Factors.

Host factors are those factors relating to the morphology and arrangement of the teeth, and composition of the saliva, which vary between individuals. Individuals with deeper pits and fissures or irregularities in the tooth surface, or those with crowded and overlapping teeth, are more prone to a build-up of plaque in these areas and therefore more likely to develop dental caries. In contrast, if the teeth have fewer crevices where plaque can accumulate, or are evenly arranged or widely spaced out, then caries is less likely to occur because the teeth can be more easily cleansed, either by mechanical means or by the action of saliva and the tongue (Zero, 1999).

Undernutrition has been associated with dental caries (Moynihan, 2003; O'Sullivan, *et al.*, 1992). Poor nutrition during development will affect the formation of the tooth, and enamel hypoplasia is often associated with undernutrition. Enamel hypoplasia consists of lines or pits in the enamel caused when enamel formation was interrupted by an episode of severe stress; when growth resumes a new layer of enamel is begun, leaving the incomplete enamel layer as a mark on the tooth surface (Aufderheide and Rodríguez-Martín, 1998). These weakened areas of enamel may be more susceptible to dental caries (Moynihan, 2003; Enwonwu, 1974; Williams and Curzon, 1986). In addition, undernourished individuals tend to have a reduced salivary flow rate due to atrophy of the salivary glands, so losing many of the beneficial actions of saliva in caries prevention (discussed below). The mineral composition of the tooth will also affect its resistance to the development of carious lesions, and will be discussed in relation to fluoride in Section 3.3.4.1.2 below.

The type and quantity of bacteria present in the mouth are likely to have an impact on the caries experience of an individual. As discussed above (Section 3.2), *Streptococcus mutans* is the most cariogenic of the oral bacteria, but other bacteria have been associated with caries to a lesser degree, including *Streptococcus salivarius*, *S. sanguis*, *S. sobrinus*, *Lactobacillus casei*, and some *Actinomyces* strains (Committee on Diet and Health, *et al.*, 1989; Zero, 1999). The age at which an infant acquires oral bacteria, and the type and quantity of bacteria acquired, will all influence the development and progression of carious lesions. However, the relationship between bacteria and caries development is not clear-cut, as the composition of the oral bacterial community varies throughout life and across tooth surfaces (Committee on Diet and Health, *et al.*, 1989), and there is evidence to suggest that large numbers of oral bacteria do not necessarily equate with high levels of acid production (dos Santos, *et al.*, 2002). Furthermore, some individuals have a higher natural oral pH than others and consequently their pH does not drop as low, or remain below critical levels for as long, as individuals with a lower resting pH (Zero, 1999).

Saliva is important in protecting against dental caries. It buffers the teeth against, and helps to control, the reductions in pH caused by the metabolisation of food substrates, so protecting the teeth against episodes of demineralisation. In addition, saliva cleanses the teeth, exerts an antibacterial action, and delivers calcium, phosphate and fluoride ions to the tooth surfaces, which inhibit demineralisation and help the action of remineralisation (Dowd, 1999; Zero, 1999; Committee on Diet and Health, *et al.*, 1989). The amount of saliva produced, and its composition, can vary between individuals. A lack of saliva prolongs the depressed pH levels caused when food substrates are metabolised by the oral bacteria. In addition, a low salivary flow rate does not clear these substrates from the mouth, and so individuals who produce low levels of saliva are more prone to developing caries (Clarkson, 1999; Zero, 1999; Committee on Diet and Health, *et al.*, 1989).

3.3.2 Diet.

A variety of factors intrinsic to the physiology of the individual can influence the caries experience of that individual, but one of the most significant factors in caries development is diet. Teeth come into direct contact with food in the mouth, and different foods affect the teeth in different ways. Some components of diet, such as sugar, place the teeth at risk of developing caries, and these are defined as cariogenic. Other aspects of diet may either protect or repair teeth, and these can be classed as cariostatic foods. The action of different foods on the teeth can be modified by the host factors discussed above (Section 3.3.1), and by behavioural factors, such as food choice and frequency of eating, and oral hygiene, discussed in Section 3.3.3 below. Trace elements, consumed via food or water, can also affect caries development, but these will be discussed in Section 3.3.4.

3.3.2.1 Cariogenic Foods.

For a food to be cariogenic the oral bacteria must be able to break down the food substrates in the mouth, producing the acid by-product that lowers the plaque pH and places the teeth in an environment that favours demineralisation. The lower the pH drop, and the longer it occurs, then the longer the period of carious attack the teeth endure. Large pH depressions are produced when the bacteria metabolise rapidly fermentable sugars (e.g. sucrose, glucose, fructose), but less of a pH drop occurs in connection with more complex carbohydrates such as starch, as the sugars in starch need to be broken down into individual sugar units before they can be metabolised (Zero, 1999). Therefore, in general, if foods contain a high proportion of sugars then they will be more cariogenic than foods that contain smaller proportions of sugars. The evidence for the role of sugars and starches in the development of dental caries will be discussed in more detail below.

3.3.2.1.1 Carbohydrates: Starches and Sugars.

Starch, a polysaccharide formed from chains of sugars joined together, is the main carbohydrate produced by plants, and it acts as an energy store. Starch is broken down (metabolised) during digestion into its individual sugars, which can then be absorbed and used as a source of energy (Department of Health, 1989). Sugars are sweet-tasting, fermentable carbohydrates that occur naturally in many foods such as honey, fruit, vegetables, and sugar cane and beet (Department of Health, 1989). Glucose is the most widely available of the naturally occurring sugars, and is found in honey, fruit and vegetables, with trace amounts present in cereal grains and flour; it is also present in starch and as a component of many disaccharides (two sugar units combined), such as sucrose and maltose. Fructose is predominantly found in fruit and honey, with trace amounts present in vegetables. Lactose is the sugar present in milk, and is found in any milk products. Maltose is a disaccharide produced during the breakdown of starch, and is found in foods containing glucose syrups. Sucrose, the most widely consumed sugar in modern Westernised countries, is a disaccharide formed from glucose and fructose. It is found predominantly in sugar cane and sugar beet, but trace amounts occur in cereal grains, flour, fruit and vegetables (Department of Health, 1989).

Sugars can be divided into two groups: intrinsic and extrinsic sugars (Moynihan, 2003; Rugg-Gunn, 2001; Department of Health, 1989). Intrinsic sugars are incorporated into the cellular structure of foods, such as fruits, vegetables and cereals, and so are mainly comprised of glucose and fructose. There is some evidence to suggest that these sugars do not pose a large risk to teeth (Moynihan, 2003). However, many fruits are acidic and may result in acid erosion of the tooth enamel, and they do contain relatively high levels of fructose. König (2000: p169) suggests that: "It would appear that fresh fruits when consumed infrequently in a normal varied diet do not contribute detectably to caries activity, but they possess a cariogenic potential which may become manifest when they are consumed frequently". Extrinsic sugars, on the other hand, are located outside the cellular structure, and these are further divided into milk sugars (i.e. lactose, identified as the least cariogenic of the sugars) and non-milk extrinsic sugars (NMES). The latter encompass all sugars added to food during processing or manufacturing, preparation or cooking, or by the individual prior to consumption. This group also includes honey and fruit juices. The NMES have been identified as placing the teeth at particularly high risk of caries activity (Moynihan, 2003), and as most added sugars in the recent history of industrialised countries have been sucrose, extracted and refined from the sugar cane and sugar beet plants, it is refined sucrose that has been associated with the high caries experience of these countries. Sucrose is generally accepted as the most cariogenic of the sugars (Zero, 1999; Jensen, 1999; Committee on Diet and Health, *et al.*, 1989); although others have suggested it is not more cariogenic than the other sugars (Moynihan, 2003) and it appears to be the sugar favoured by most cariogenic bacteria (Jensen, 1999). Dried fruit also has high levels of NMES, as the intrinsic sugars are released from the cells when the cellular structure breaks down during the process of drying. In the fourth century B.C. Aristotle hypothesised that dried fruits (sweet figs) were cariogenic, commenting on their tendency to stick to the teeth (Hardwick, 1960; Committee on Diet and Health, *et al.*, 1989), and recently König (2000: p169) notes that studies "clearly indicate a high cariogenic potential" with regard to dried fruits.

3.3.2.1.2 Evidence for the Cariogenicity of Sugars.

A vast array of clinical literature has repeatedly demonstrated the link between sugar and dental caries. Observations on the caries experience of different groups of people in different circumstances have all contributed to the current understanding of the role of sugar as an aetiological factor. For example, during the Second World War many populations experienced lowered caries rates and this was attributed to the rationing of sugar, with an increase in caries accompanying the end of rationing (Moynihan, 2003;

König, 2000; Committee on Diet and Health, *et al.*, 1989). Moynihan (2003) also reports that children consuming sugary medicines on a long-term basis are prone to higher levels of caries than healthy children. The inhabitants of the island of Tristan da Cunha are often cited as an example where dental caries increased with increased availability of sugar (Moynihan, 2003; Drummond and Wilbraham, 1957). The population of this remote island subsisted on a traditional diet low in sugar and cereals and consisting mainly of potatoes, fish, eggs and a small amount of milk and vegetables. When their teeth were examined in 1932 the caries rate was found to be extremely low. However, from the late 1930s onwards they experienced increasing contact with passing ships, and with the establishment of regular trade to the island they began to receive quantities of flour, sugar and processed foods. The change in their diet corresponded with a marked increase in caries prevalence across all age groups. Another observational study concerned the children living in Hopewood House children's home, South Australia (Moynihan, 2003). These children were fed a strict diet low in sugar and refined flour, and their caries experience was much lower than that of equivalent non-resident children. Upon leaving the home their rate of caries development increased to match that of the non-resident children.

A problem with studying caries prevalence in humans is that it is difficult to control for variation in diet and other influencing factors. One of the earliest studies to show the connection between sugar and caries was carried out in the Vipeholm mental institution in Sweden between 1945 and 1953, and involved controlling the diet consumed by different groups of people and observing the effect this had on their teeth. This study is now considered very unethical, and it could not be repeated today. Moynihan (2003) describes the study in detail and reviews the results obtained. The subjects were given refined sugars of different consistencies, with or in between meals, and an increase in caries frequency was observed in those individuals with frequent sugar consumption. None of the inmates were able to perform oral hygiene, and fluoride was not available (König, 2000), so in some ways this study provides an indication of caries development in adults purely as a response to changes in diet. However, the subjects were living in an artificial environment, and were mentally ill or physically handicapped and so may not have had normal oral physiology and possibly did not exhibit normal eating behaviour. Their responses to the choices given them in terms of food consumption might not have been the same as those made by a healthy individual living in a normal environment. Ettinger (1999) notes that mentally retarded individuals are one of the groups at a high risk of developing dental caries, although he does not give a reason why.

Another intervention study was that carried out in the University of Turku, Finland in the early 1970s (reviewed by Moynihan, 2003; and the Committee on Diet and Health, *et al.*, 1989). This study observed the effect on the dental caries incidence of three groups of individuals of consuming diets containing sucrose, fructose, or xylitol over a period of two years. Those consuming the xylitol diet showed very little caries increment, and although both groups consuming the sugar diets had an increase in caries, those consuming the sucrose diet had considerably more caries than those following the fructose diet.

A large number of studies have investigated caries prevalence in modern populations and tried to relate this to sugar consumption, the majority of which have focussed on children. In a cross-sectional study, dos Santos *et al.* (2002) observed that levels of sugar consumption were much higher in young children with nursing caries (rampant caries of the deciduous dentition associated with bottle-feeding, Kashket and DePaola, 2002) or pit-and-fissure caries than in children with no carious lesions at all. A longitudinal study of Finnish children, where diet was recorded between the ages of 7 months and ten years, concluded that those children with a higher sucrose intake had a higher caries incidence, and that a high sucrose intake therefore increases the risk of dental caries (Ruottinen, *et al.*, 2004). Many recent studies of western countries have not found such a strong link between sucrose consumption and dental caries. For example a cross-sectional study of Spanish schoolchildren could not find a significant association between caries development and sugar, but they stress that this result could have been due to the population in question having a low caries prevalence to begin with or to problems in classifying different foods in the diet (García-Closas, *et al.*, 1997). A study of Swedish children also failed to find a positive correlation between an increasing consumption of sugar and increased dental caries prevalence, and this was attributed to oral hygiene practices and the use of fluorides (Stecksén-Blicks, *et al.*, 2004).

Understanding the relationship between dietary sugar and dental caries development in modern populations is complicated by factors such as oral hygiene practices, the use of fluoride, and dental care. Since the 1970s the strong relationship between dental caries and sugar has been obscured by many of these factors, especially in western countries (Marthaler, *et al.*, 1996; Zero, 1999). In a study of caries prevalence in 90 countries an overall association between caries and dietary sugar was found, but this association was not observed when the industrialised countries were examined on their own (Woodward and Walker, 1994). In many cases it appears that sugar consumption has remained the same, but other factors are acting to lower caries prevalence (Marthaler, 1990; Zero, 1999). In comparison, sucrose consumption is increasing in developing countries, as more people adopt a westernised diet and lifestyle, raising fears that caries prevalence will rise as a result (Ismail, *et al.*, 1997).

3.3.2.1.3 Evidence for the Cariogenicity of Complex Carbohydrates.

Sugars are not the sole cause of dental caries; starches have also been implicated in caries development, but to a lesser degree. Populations subsisting on diets low in refined sugar have often been found to have low caries prevalence rates, but in general some caries does still occur (Drummond and Wilbraham, 1957; Elderton, 1990). Starch usually has low cariogenicity as it is insoluble and needs to be broken down into simpler sugars before it can be metabolised by oral bacteria, and the starch is usually cleared from the mouth before this can happen (Zero, 1999). However, there are many factors that may affect the cariogenicity of starch, including whether it is refined or unrefined, cooked or raw (Moynihan, 2003; Elderton, 1990; Rebelo Viera, *et al.*, 2002). Unrefined starches have a particularly low association with caries, as do uncooked starches, as they are insoluble and cannot be easily broken down by salivary amylase (Jensen, 1999; Zero, 1999). When cooked, the risk of caries development increases slightly, as the composition of the starch molecules changes, allowing increased retention in the mouth and encouraging their breakdown into maltose and a small amount of glucose, but cooked starches are still less dangerous than sugars (Jensen, 1999; Moynihan, 2003; Rebelo Viera, *et al.*, 2002). Processing starch by grinding it into fine powder or refining it, especially if cooked, does increase the risk of caries development, but again not as much as sugar consumption (Moynihan, 2003).

There is some evidence that there are differences in the cariogenicity of starches from different plant origins. A study conducted by Sreenby (1983) discovered that the relationship between caries and cereals varied according to the type of cereal: wheat was associated with increased caries levels in 47 countries, whereas rice showed no correlation, and maize consumption was linked with lower caries levels. Although Moynihan (2003) has suggested that these results do not take account of sugar consumption, a study by Tayles *et al.* (2000) also found an association between a high rice consumption and low caries prevalence in Thailand. It is difficult to separate the action of sugars and starches in caries development, as the two are frequently consumed together. Individuals with hereditary fructose intolerance cannot tolerate sucrose and fructose, but can eat starch. These individuals consume a diet containing a higher than average starch content, but a low level of sugars, and display low levels of dental caries (Moynihan, 2003).

3.3.2.1.4 Food Combinations and Patterns of Consumption.

Many studies have shown that it is not the amount of sugar consumed, but the frequency with which it is consumed, that is most deleterious to the health of the teeth. In addition, the ways in which foods are combined, the texture of the food and when it is eaten are also important in determining the cariogenicity of foods (Moynihan, 2003; Zero, 1999; Marthaler, *et al.*, 1996; Jensen, 1999; Elderton, 1990; Committee on Diet and Health, *et al.*, 1989; Lingström, *et al.*, 2003). The more often food is consumed then the more often the oral bacteria are provided with substrate to metabolise, and the more often the teeth are exposed to low pH levels and episodes of demineralisation, with less chance to regain the minerals lost during the resulting shorter periods of remineralisation. If the frequently consumed foods are sugary in nature, then the risk of carious attack becomes more serious. Holt (1991) studied the amount and type of food and drink consumed between meals by English children, and concluded that children who consumed more snacks and drinks had a higher level of dental caries than those that did not snack between meals as often. A study of Jordanian children also observed that caries prevalence was associated with the consumption of confectionary and tea sweetened with sugar between meals (Sayegh, *et al.*, 2002). It is often difficult to separate the effects of quantity and frequency of sucrose consumed, as the two are usually closely linked (Moynihan, 2003).

Other studies have investigated the link between the timing and frequency of eating sugary foods and caries prevalence. An investigation of the relationship between consuming foods high in non-milk extrinsic sugars before sleeping and dental caries recorded a positive correlation between the two (Levine, 2001). Salivary flow rate is lower during sleep, so food consumed before bedtime is not cleared from the mouth as quickly and pH levels remain depressed for longer.

As well as suggesting that consuming sugary foods outside mealtimes, and that frequency of consumption, were more likely to place teeth at risk of developing caries, the Vipeholm study indicated that the consistency of the food consumed is important (Moynihan, 2003). During this study it was observed that individuals eating additional sugar at mealtimes tended to not demonstrate a marked caries increase, but those consuming the sugar in between meals experienced the greatest caries increment. The highest caries rates were observed in the individuals consuming caramels or sticky toffees between meals. Such a large increase in caries was observed that the sweets were withdrawn, and consumption in between meal times was not allowed, which resulted in a lower caries development from then on. Sticky foods that adhere to the teeth, such as toffees or dried fruits, place the teeth at risk of developing caries. The longer the food is retained in the mouth, the longer it is available for metabolisation by the oral bacteria, then the longer the teeth are exposed to depressed pH levels and suffer demineralisation (Jensen, 1999; Zero, 1999).

Sugar combined with processed and cooked starch is a particularly cariogenic food, as it is sticky and adheres to the teeth or gets impacted into fissures, holding the sugar in the mouth for longer periods than it might have been if consumed alone or in another form (Moynihan, 2003; Jensen, 1999). This acts to extend the period of low plaque pH and active demineralisation. Campain *et al.* (2003) observed that foods with a relatively low proportion of sugar but high levels of starch were associated with the development of dental caries in adolescent Australians. García-Closas *et al.* (1997) found an association between cooked foods containing a combination of sugar and starch and caries experience in Spanish children. Stecksén-Blicks *et al.* (2004: p154) conclude that "sugar consumed in drinks and sticky products may thus jeopardise dental health more than direct sugar consumption."

3.3.2.2 Cariostatic Foods.

3.3.2.2.1 Cheese and Milk.

Some foods have displayed properties that help protect teeth against dental caries, and there have been various studies of the cariostatic action of cheese and milk (Herod, 1991; Kashket and DePaola, 2002). The first study to investigate the effect of cheese on caries development in humans found that cheese reduced the extent of demineralisation caused by sucrose by an average of 71%, and that, following cheese consumption, the plaque pH drop was less and returned to normal in a shorter space of time, and the salivary flow rate increased dramatically and remained high; in a few individuals the pH drop associated with sugar consumption was eliminated altogether (Silva, *et al.*, 1986). A more recent investigation explored whether cooked cheese consumed as part of a mixed meal exhibited similar beneficial effects, and the results confirmed that it did (Moynihan, *et al.*, 1999). Jensen (1999) states that cheese may reduce root surface caries by 52%, and enamel caries by 10%.

The beneficial effects of cheese and milk have been attributed to a variety of factors. Cheese stimulates the flow of saliva, which buffers the plaque pH and clears food from the mouth quickly (Moynihan, *et al.*, 1999; Herod, 1991; Silva, *et al.*, 1986; Kashket and DePaola, 2002). The drop in pH is therefore not as great and returns to neutral within a short space of time, and the source of substrate for the oral bacteria is removed. Both these factors prevent a prolonged depression of oral pH levels so shortening the period in which the teeth are exposed to an environment favourable to demineralisation. In addition, the calcium and phosphate ions contained in cheese help inhibit demineralisation (i.e. the loss of these ions from the tooth structure) and promote remineralisation (the incorporation of these ions into the tooth structure) (Moynihan, *et al.*, 1999; Silva, *et al.*, 1986; Herod, 1991; Kashket and DePaola, 2002). Moynihan *et al.* (1999) observed that the increase in plaque calcium concentration was highest when a cheese meal was consumed, even though another meal (lacking cheese) actually had a higher calcium content. They suggest that the calcium in cheese exists in a form more readily available for diffusion into the plaque. Silva *et al.* (1986) hypothesise that peptides in the cheese accelerate the rise in pH, and that fatty acids inhibit the action of the cariogenic bacteria, although Herod (1991) suggests that there is conflicting evidence on the latter point. Recent studies have identified a group of milk proteins that are believed to contribute to the protective effect through attaching themselves to the surface of the enamel, acting to slow down the demineralisation process (Grenby, *et al.*, 2001).

The evidence of all these studies indicates that cheese and milk do exert a strong cariostatic action, and that this is achieved through a variety of means. All conclude that eating cheese at the end of a meal is likely to benefit the health of teeth considerably, and the results of Moynihan *et al.* imply that even if cheese is eaten during a meal its beneficial effects are still evident.

3.3.2.2.2 Other Cariostatic Foods.

Foods that contain high levels of fluoride, such as marine products and tea, will be beneficial to teeth, and these are discussed in Section 3.3.4.1.3. Moynihan (2003) discusses other foods that may display cariostatic qualities, but none are as effective as cheese and milk. In addition to fluoride, tea contains polyphenols and flavanoids, which exert a protective effect (Moynihan, 2003; Jensen, 1999). Apples also contain polyphenols, and stimulate saliva (Moynihan, 2003), but they do contain a large proportion of fructose and are acidic which may counteract any benefit gained (König, 2000). Similarly, although honey and chocolate contain factors that protect against caries development, these are far outweighed by the high sugar content (Moynihan, 2003; Jensen, 1999). Animal studies have suggested that inorganic phosphates present in plant foods protect the teeth, but results have been inconsistent in humans (Moynihan, 2003; Jensen, 1999). Likewise, plant phytates have proved effective as protection against caries when isolated, but do not have the same effect when they are consumed as part of a normal diet (Moynihan, 2003).

3.3.3 Behaviour.

From the discussion of diet above it is clear that individual behaviour relating to food choice will have an impact on their experience of dental caries. The type and combination of foods chosen, the way in which they are prepared for consumption, the texture of the foods selected, the frequency with which they are eaten and the timing of consumption will all have a bearing on the development of carious lesions (see Section 3.3.2.1.4). Another factor that will influence caries experience is oral hygiene: whether any kind of oral hygiene is attempted and, if so, what type of oral hygiene is practiced, and how often.

Mechanical cleaning of the teeth helps to remove accumulations of plaque and food debris, but cleaning needs to be thorough and repeated at regular intervals for it to be effective (Wu, *et al.*, 2001). The populations of Westernised countries tend to use toothbrushes and toothpastes (often fluoridated), and studies on trends in caries prevalence in these countries have tended to attribute the recent drop in prevalence in part to improved oral hygiene (König, 2000; Marthaler, 1990; Marthaler, *et al.*, 1996). Higher caries rates are often observed in individuals from lower social classes, and one of the reasons for this is given as poor oral hygiene, coupled with less regular attendance at the dentist, less knowledge of health issues, and a tendency to consume more cariogenic foods (Elderton, 1990). In large parts of the world, the chewing stick is the preferred method for cleaning the teeth, and the combination of mechanical cleaning and enhanced salivation resulting from its use can be just as efficient as using a toothbrush. In fact, some studies have reported a lower caries prevalence rate in individuals using chewing sticks than in those using toothbrushes (Wu, *et al.*, 2001). Toothpicks are another means by which oral hygiene can be attempted, and their use was recorded (in conjunction with tooth-brushing) in a sample of children from Ghana (Åstrøm and Haugejorden, 2000). Oral hygiene is not a part of all cultures, and many populations have a low caries prevalence rate despite not cleaning their teeth. For example, the majority of village peasants in Nigeria had extremely low caries rates, yet had large accumulations of plaque, calculus and food debris on their teeth (Enwonwu, 1974). Their low caries prevalence was attributed to the diet high in starch and low in sugar.

3.3.4 Trace Elements.

Trace elements are defined as "those elements of the periodic table that occur in the body in micrograms per gram (μg/g) of body weight or less" (Nielsen, 2000: p856). Some of them are essential for growth and development, and the maintenance of health, such as iron and iodine, and their lack is detrimental to the organism. Others may be non-essential, but can still have an impact on the health of the organism (Nielsen, 2000). Several trace elements have been found to affect the development of dental caries, and these will be discussed below. The effect of fluoride will be discussed in detail, as there have been many clinical studies and its benefits are widely known. Other trace elements, molybdenum, selenium and vanadium, will be discussed more briefly as their effects are less well understood and they have not been the subjects of many studies.

3.3.4.1 Fluoride.

Fluoride (F) is an ion formed when the gaseous element fluorine bonds with an electron, and it can join with alkali metals to form soluble salts (Edgar, 1990b). Despite being a relatively common element, most of the world's fluoride is not biologically available, being tied up in minerals and other compounds (World Health Organization, 1994). Biological availability is determined by several factors, including the amount of water available, acidity of the soil, the solubility of the fluoride compound, and the presence of other minerals. All water contains some degree of fluoride, but natural concentrations vary. Most freshwater sources contain levels of less than 0.5 ppm (parts per million), but higher levels occur in some areas, with the highest recorded concentration being 2,800 ppm from the waters of Lake Nakuru, in the Rift Valley, Kenya (World Health Organization, 1994). Seawater fluoride concentrations are usually in the region of 0.8-1.4 ppm, and areas with marine geological deposits tend to have raised fluoride levels (World Health Organization, 1994). Fluoride concentrations in the water may be inconsistent over small areas, and "even within one village community, different wells often show widely divergent fluoride contents, apparently as a result of differences in the local hydro-geological conditions" (World Health Organization, 1994, p4).

3.3.4.1.1 The Effects of Water Fluoridation on Caries Prevalence.

The relationship between fluoride and dental caries was established during the first half of the twentieth century, and its history has been summarised by several authors (Knox, 1985; Warren and Levy, 1999; Edgar, 1990b). Essentially, by the end of the nineteenth century, the drinking waters of certain regions were associated with mottling of the enamel, now known as dental fluorosis. Other studies noted that individuals with mottled enamel had fewer carious lesions than those with normal enamel, and a common cause was suggested for both. In the 1930s the presence of high levels of fluoride in the drinking water was identified as the cause of dental fluorosis. Further studies of dental caries and natural fluoride confirmed the beneficial effects of optimal levels of fluoride in lowering caries prevalence, and the possibility of deliberately adding fluoride to public water supplies was investigated.

The first trial of artificial fluoridation took place in 1945, in Grand Rapids, Michigan, and during the early 1950s several more American cities followed suit (Knox, 1985). Comparative trials began in four areas of Britain in 1955-6, following the results of the American experience, and the government declared its support for water fluoridation in December 1962. Despite this, only 10% of the British population received fluoridated water in 1985, predominantly in the West Midlands, compared to 46% of the US population in 1980 (Knox, 1985) and 62% of the US population receiving public water supplies in 1999 (Warren and Levy, 1999). Whilst some areas of Britain have since implemented fluoridation schemes (Gray and Davies-Slowik, 2001), others have ceased to fluoridate their water supply (Thomas, *et al.*, 1995). Every year since 1991, the Department of the Environment has published a map showing the areas supplied with artificially, and naturally, fluoridated water (Department of the Environment, 1991). They also state the current position regarding artificial water fluoridation in the UK, according to the Water (Fluoridation) Act 1985 and the Water Industry Act 1991, whereby water companies are empowered to fluoridate the water supply at the optimum level of 1.0 ppm upon the written request of a District Health Authority (Department of the Environment Transport and the Regions, 1998; Department of the Environment, 1991). However, there have been over 50 cases where a water company has refused to implement water fluoridation schemes upon the request of a health authority, and it is recognised that current fluoridation laws are flawed (Lennon, 2000). Studies have confirmed that the effect of artificial fluoridation is the same as that of naturally high fluoride levels in the drinking water (Backer Dirks, 1974; Ericsson, 1974).

During the last three decades, the high caries levels observed in most Western, industrialized countries has been falling, and in general this has been attributed to the introduction of fluoride (Zero, 1999; Irigoyen and Sánchez-Hinojosa, 2000; Ettinger, 1999). Early epidemiological studies of water fluoridation during the 1960s and 1970s show significant reductions in the prevalence of caries in fluoridated areas. The majority of the studies reviewed by Backer Dirks (1974) showed a reduction of around 50%, and some early studies have even shown a reduction of up to 80% (Künzel and Fischer, 1997). Studies of fluoridation in Anglesey, one of the four original British test-areas, continued to confirm the 50% reductions in caries observed in 1955: in 1974, 15-year-old children from Anglesey receiving optimal water fluoridation had 44% fewer attacked teeth, and 48% fewer carious lesions, than the control population from mainland Gwynedd, where fluoride levels in the water were less than 0.01 ppm (Jackson, *et al.*, 1975). The World Health Organisation cites reductions in caries prevalence due to fluoridation of 40-49% in the deciduous teeth, and 50-59% in the permanent teeth (World Health Organization, 1994). This beneficial effect of fluoridation only persists as long as the individual is exposed to fluoride (Backer Dirks, 1974).

Fluoride appears to have the greatest protective effect on the smooth surfaces of the teeth, with the pits and fissures being least protected (Edgar, 1990b). Backer Dirks (1974) notes that whilst fluoride was responsible for a 35-40% reduction in caries for the pits and fissures, it caused a 70-75% reduction in proximal caries, and a reduction of around 85% for the smooth surfaces of the teeth. There is also evidence that fluoride is particularly effective in protecting against root surface caries (World Health Organization, 1994). The anterior teeth generally benefit more than the posterior teeth, with incisors showing an 83% reduction due to fluoride, compared to a 47% reduction for molars (Backer Dirks, 1974; Edgar, 1990b). The latter may partly be due to the presence of pits and fissures in the molar teeth, and the lesser impact of fluoride on caries of these surfaces.

In contrast, some of the more recent studies on the effects of water fluoridation have provided less conclusive results. Since the 1980s many studies no longer show the expected differences between fluoridated and non-fluoridated populations (Seppä, *et al.*, 2002; Künzel and Fischer, 2000). Previously, periods of interrupted fluoridation were associated with rises in caries prevalence, which dropped following the resumption of optimal fluoridation. Recently, studies of areas where fluoridation was stopped no longer found this anticipated rise in caries prevalence, and in some cases the caries prevalence even dropped further when fluoridation was terminated (Künzel and Fischer, 2000, 1997). These findings can be understood if it is realised that the recent overall trend towards lower caries prevalence has been more pronounced in non-fluoridated areas, and so in many cases their caries levels now approach those of fluoridated areas. It is clear that factors other than water fluoridation are having a major effect on modern caries prevalence.

In Europe, these changes have been attributed in part to the availability of fluoride in other sources, for example, fluoridated toothpaste, which has been widely used since the 1970s, and fluoride tablets, gels and mouthwashes (World Health Organization, 1994; Künzel and Fischer, 1997; Seppä, *et al.*, 2002). In some areas of Europe where water fluoridation is no longer (or was never) practiced, other systemic sources of fluoride are provided instead. Switzerland has been fluoridating salt used for both household and industrial use since 1955, with similar results to those observed for water fluoridation, and France and Germany have fluoridated household salt since 1986 and early 1991, respectively (World Health Organization, 1994; Irigoyen and Sánchez-Hinojosa, 2000; Schulte, *et al.*, 2002). Improvements in European dental care and health education have been cited as important factors, with better public awareness of oral health leading to improvements in oral hygiene practices and regular visits to the dentist (Seppä, *et al.*, 2002). Most studies concur that the lowering caries rates cannot be attributed to changes in European diet, as there is little evidence that the amount of sugar consumed has changed (Künzel and Fischer, 1997). However, it is possible that the form in which sugar and other carbohydrates are consumed has changed, with more consumption of unrefined brown flours and sugars instead of refined white sugar and flour (Zero, 1999).

The changing pattern of response to water fluoridation is not solely a European phenomenon. This trend has been observed elsewhere, although the explanatory factors proposed may vary considerably for different countries. For example, in La Salud, Cuba, water fluoridation ceased in 1990 but oral health in children continued to improve, despite the lack of several elements identified as being of primary importance in reducing the European caries prevalence, including fluoridated toothpastes, fluoridated salt, fluoride tablets, toothbrushes and dental floss (Künzel and Fischer, 2000). However, it transpired that children between 2-5 years old received up to two applications of fluoride varnish to their teeth each year, and all children receive fluoride mouthrinses once a fortnight during school terms. In contrast to Europe, diet emerged as a significant contributing factor. Food has been rationed since 1990, tinned foods, meat and meat products are scarce and the principal foods are rice, potatoes, bread and vegetables. Half the sugar consumed was in the form of unrefined brown sugar, and no sweets were available except for a small amount of homemade products. Parallels can be seen in the drop in British caries prevalence that occurred during both world wars, when food was rationed and sugar was scarce (Hardwick, 1960).

Although some recent studies appear to show that there is little benefit to be obtained from fluoridated water, in reality a variety of complex, interacting factors, usually including other sources of fluoride, have been shown to account for these findings. Indeed, Seppä et al. (2002) observe that just because fluoridation is now of minor benefit in Finland does not mean that it is ineffective in other countries with different circumstances. They specifically cite the UK and the US as countries that should continue with water fluoridation, as significant differences in caries prevalence still occur between fluoridated and non-fluoridated regions. This conclusion is confirmed by recent studies in Britain that continue to show the benefits of water fluoridation. For example, fluoridation in Anglesey became intermittent in 1987, and was terminated in 1991; during this period caries prevalence rose steadily and it has since reached the high levels found on mainland Gwynedd (Thomas, *et al.*, 1995). Studies monitoring the introduction of fluoridated water in West Midland towns continue to record significantly reduced caries prevalence in the fluoridated areas (Gray and Davies-Slowik, 2001). It can therefore be accepted that fluoride does have a clear effect in lowering caries prevalence when it is present at optimum levels in the drinking water, which is accepted as 1 ppm for temperate areas.

3.3.4.1.2 The Action of Fluoride in Protecting Against Caries.

Originally, it was thought that fluoride exerted its protective effect predominantly through altering the composition of enamel as the tooth developed, and, therefore, that the individual had to be exposed to optimal fluoride concentrations during childhood to gain any real benefit (Fabian Society, 1975; Warren and Levy, 1999). It is now known that fluoride acts in several ways to prevent caries formation, and that the most important of these occurs after the teeth have erupted, with regard to its role in remineralisation (Edgar, 1990b; World Health Organization, 1994; Warren and Levy, 1999). Before discussing this in more detail, the way in which fluoride is incorporated into the enamel structure is discussed.

Hydroxyapatite crystals are an essential component of enamel and bone structure, and consist of calcium, phosphate and hydroxyl ions bonded together. Because fluoride ions have similar dimensions to the hydroxyl ions, they can replace some of these to form fluoroapatite crystals, which are then incorporated into the enamel structure (Edgar, 1990b). Fluoroapatite is much more stable than hydroxyapatite, due to the larger size, more uniform shape, and closer proximity of the crystals. This increased stability imparted by the presence of fluoride decreases the solubility of the enamel in acid, and therefore increases the resistance of the tooth to developing a carious lesion. However, even pure fluoroapatite, which is the least acid-soluble in the calcium-phosphate series, demineralises in a strong acid solution (Edgar, 1990b; Zero, 1999).

Any fluoride present in the soft tissue fluids surrounding the developing tooth will be incorporated into the bulk of the enamel structure as described above, strengthening the teeth against later carious attacks. Fluoride can also be incorporated into the surface enamel following the eruption of the teeth into the mouth, and it is this action that is now believed to be of prime importance in preventing caries. Once the teeth have erupted, they experience the daily fluctuations in plaque pH and the accompanying demineralisation and remineralisation process described above. Teeth are most vulnerable to caries during the first three years after eruption, as demonstrated by the modern incidence of crown caries being at its highest during childhood and adolescence (Elderton, 1990; Zero, 1999). When the enamel is first exposed to demineralisation (i.e. a carious attack) it initially loses the most soluble carbonate components. If fluoride is present during remineralisation, it is preferentially incorporated into the enamel structure to form fluoroapatite, thus increasing stability and decreasing solubility (Zero, 1999). This remineralised enamel, with increased amounts of fluoroapatite, will subsequently be more resistant to demineralisation than the surrounding enamel, so, paradoxically, a remineralised carious lesion can be more resistant to future development of caries than an unaffected area of the tooth (Silverstone, 1990). Not only does fluoride have an important role in post-eruptive strengthening of enamel and in healing incipient carious lesions, it also actively promotes the remineralisation process and so actually increases the speed with which it is incorporated into the enamel (World Health Organization, 1994; Edgar, 1990b).

Fluoride inhibits the action of many enzymes, and so its presence in saliva and plaque interferes with the metabolisation of sugars by the oral bacteria, reducing acid production and shortening the periods during which demineralisation can occur (Edgar, 1990b; Broukal and Zajícek, 1974). The effect of fluoride in inhibiting bacterial acid production gets stronger as pH levels get lower (Edgar, 1990b). These effects are more pronounced when fluoride is present in high concentrations, such as that found in toothpastes and other modern topical applications, although a slight effect has been seen in individuals consuming fluoridated water (Edgar, 1990b). When fluoride is present in high concentrations, it may even kill the pathogenic bacteria themselves (Edgar, 1990b; Broukal and Zajícek, 1974). In addition, animal studies have noted that the presence of fluoride affects the morphology of the developing teeth, resulting in smaller teeth with rounder cusps and shallower fissures, and that similar changes have been observed in people from high-fluoride areas (Edgar, 1990b). Shallower fissures would discourage the build-up of plaque, reducing the vulnerability of the tooth to fissure caries.

Fluoride is most effective if low levels are constantly present in the mouth, and it is found in the saliva, on the surfaces of the teeth and soft tissues, and in higher concentrations in plaque and calculus (World Health Organization, 1994; Edgar, 1990a, 1990b). Fluoride levels in saliva and plaque vary according to the fluoride levels in the drinking water and those in calculus may be up to a thousand times the levels present in saliva (Edgar, 1990b). All the fluoride in saliva is in the active ionic form, and the saliva delivers this to the tooth surfaces where it can act to prevent demineralisation, encourage remineralisation and be incorporated into the enamel structure (Edgar, 1990b; Dowd, 1999). Although much of the fluoride stored in plaque and calculus is believed to be inactive, it is possible that active ions are slowly released after exposure to carbohydrates when plaque pH is lowered (Edgar, 1990b). Although fluoride appears to be most effective at inhibiting the initiation of carious lesions rather than inhibiting lesion progression (Zero, 1999), carious lesions are more likely to progress in the absence of fluoride (Silverstone, 1990).

3.3.4.1.3 Sources of Fluoride Ingestion.

About 75-90% of the daily fluoride intake is absorbed through the alimentary tract, with more being absorbed from liquids than from solid foods, although high levels of calcium in the diet reduces fluoride absorption (World Health Organization, 1994). Aside from drinking water, the main source of fluoride for many people is tea, which has naturally high fluoride concentrations. The plant itself contains 3.2-400 mg of fluoride per kilogram, and infusions of normal tea can contain up to 8.6 ppm (World Health Organization, 1994), with a mean of around 1.5 ppm if made with non-fluoridated water (Warren and Levy, 1999; Edgar, 1990b). The mean for decaffeinated tea is higher, at 3.19 ppm, and that of herbal tea is lower, at 0.05 ppm

(Warren and Levy, 1999). Green teas may contain up to 10 ppm in an infusion (Jensen, 1999). Increased tea consumption may help protect against caries, but only if sugar is not added (Edgar, 1990b).

Fluoride concentrations in most unprocessed foods are usually low, but can increase if they are processed in water containing high fluoride levels; these include foods such as boiled vegetables, stews, soups, jams and preserves, and beer (Edgar, 1990b; World Health Organization, 1994). As 99% of the fluoride in the body is associated with calcified tissues, any foods containing bones will be more likely to have higher fluoride concentrations (World Health Organization, 1994). Seafood contains high levels of fluoride, with levels of over 40 ppm found in dried seafood (Warren and Levy, 1999) and levels exceeding 250 ppm have been found in products made from whole sea fish (Ericsson, 1974). Other studies have highlighted that high levels of fluoride are found in fish bones and skin, but not the flesh, and high fluoride levels may be consumed when eating tinned fish as the bones and skin may be consumed (Edgar, 1990b). Chicken may also have high levels of fluoride, in the region of 10 ppm, and, again, most of this is in the bones (Warren and Levy, 1999). White grape juices have also been cited as having high levels of fluoride, with concentrations of up to 6.8 ppm and a mean of 1.33 ppm, although this was attributed to the fluoride-containing insecticides sprayed on the grapes (Warren and Levy, 1999). The levels of fluoride ingested by infants has been investigated extensively, due to concerns that consumption of dried formula milk mixed with fluoridated water results in abnormally high ingestion of fluoride compared to the low fluoride levels in human milk (below 0.05 ppm) (Warren and Levy, 1999; Ericsson, 1969).

The optimal level of fluoride in the water has been identified as 1 ppm in temperate areas, and levels of less than 0.7 ppm are regarded as low and insufficient to protect against caries (Warren and Levy, 1999; Edgar, 1990b). However, in warmer climates people tend to drink more water and so the optimal level of fluoridation is lower, and usually recommended as being around 0.7 ppm. Some studies have suggested that this is too high and lower optimal levels should be recommended instead; for example a study in Sri Lanka suggested a level of around 0.3 ppm to be appropriate (Ekanayake and van der Hoek, 2002). Increasing the level of fluoride beyond the optimal level has little impact on caries prevalence and makes the development of dental fluorosis more probable. Individual patterns of water consumption will affect the amount of fluoride ingested from the water (Warren and Levy, 1999).

Edgar (1990b) reports that the average fluoride intake per day in the UK is 1-3 mg in non-fluoridated areas, and that this figure should be doubled for fluoridated areas; fluoride intake may reach 8-10 mg a day in individuals who consume large amounts of tea. Warren and Levy (1999) state that between 0.05-0.07 mg of fluoride per kilogram of body weight is the optimal level of fluoride consumption. It has been noted that there is less need for water fluoridation in Japan, due to the large proportion of the diet consisting of fluoride-rich seafood, coupled with copious tea consumption (Ericsson, 1974). High doses of fluoride (40mg+ daily) have been investigated as a prevention and treatment for osteoporosis (World Health Organization, 1994; Warren and Levy, 1999; Ericsson, 1974), and have also been used to manage Paget's disease when it is in the osteolytic phase (Edgar, 1990b).

3.3.4.1.4 Toxic Effects of Fluoride.

Concern has been expressed about the safety of high concentrations of fluoride in drinking water. As with any substance, ingestion of large amounts of fluoride over a short space of time can be toxic, resulting in nausea, vomiting, and, in extreme cases, death. Fatal fluoride poisoning in an adult weighing c. 70kg would result after ingestion of 5-10g of fluoride, and after 320mg in a 10kg child (Warren and Levy, 1999). These figures are far in excess of the average daily consumption of fluoride discussed above. Many studies have investigated the safety of water fluoridation in response to public anxiety, for example Knox (1985) and Ericsson (1974). All have found that low levels of fluoride, as provided in fluoridated water, are safe, with the only side effect being an increased prevalence of dental fluorosis.

The association of fluoride with dental fluorosis, which predominantly affects the permanent teeth, has already been mentioned in connection with the discovery of the relationship between fluoride and caries. Mild dental fluorosis is manifested as white opaque areas of the enamel, which may become stained brown if the teeth are affected more seriously. In severe cases of dental fluorosis, the enamel is brown and prone to chipping and wear (Edgar, 1990b). Dental fluorosis results when an inordinate amount of fluoride is ingested during the period of tooth development, and it tends to be more common in fluoridated areas. When fluoride is present in the drinking water at 1 ppm, extremely mild dental fluorosis is developed by only 10% of the population, which is the situation in Britain, and there is some evidence that low levels of fluoride actually prevent idiopathic mottling of the enamel (World Health Organization, 1994; Edgar, 1990b). At levels of 6 ppm, all teeth exhibit fluorosis, and 50% of these cases are severe (Edgar, 1990b). A study of fluorosis and caries prevalence in Sri Lanka, where natural fluoride levels ranged from 0.05 to 6.1 ppm, found that severe dental fluorosis was found in the areas where drinking water contained high levels of fluoride, and that these areas also had higher levels of caries (Ekanayake and van der Hoek, 2002). Individuals with mild fluorosis had the lowest prevalence of caries, lower than individuals with no dental fluorosis at all. It was suggested that teeth suffering from severe fluorosis were brittle and contained many irregularities of the enamel, making them more vulnerable to developing caries (Ekanayake and van der Hoek, 2002). Providing young children with fluoride supplements and fluoridated toothpaste has been identified as a major risk factor for developing dental fluorosis in Britain, particularly if they reside in a fluoridated area. Young children accidentally swallow much of the inappropriately large portions of toothpaste used during brushing, and when used before two years of age the likelihood of fluorosis development is high. They are also at more risk if they are fed dried formula milk rehydrated with fluoridated water (Warren and Levy, 1999).

Skeletal fluorosis develops when the individual is exposed to excessively high fluoride levels for a long period of time. Fluoride is incorporated into the bone structure as fluoroapatite as the bone remodels, increasing bone mass and reducing bone quality, resulting in dense, brittle bones (Warren and Levy, 1999). In temperate areas, water fluoride levels approaching 5 ppm are not associated with any signs or symptoms of skeletal fluorosis, and it is only likely to occur in individuals consuming water with levels of over 10 ppm fluoride content (World Health Organization, 1994). Radiological thickening of the bones without the clinical symptoms of fluorosis has been observed in populations in the southern United States, where fluoride is present at 8 ppm in the water and around 12-16 mg of fluoride is ingested a day (Edgar, 1990b). In tropical areas, skeletal fluorosis can occur on exposure to 6 ppm of fluoride in the drinking water (World Health Organization, 1994), and is endemic in India where fluoride intake is around 20 mg per day (Edgar, 1990b). In Britain skeletal fluorosis is uncommon, and cases are usually those of individuals exposed to exceptionally high doses during industrial work (World Health Organization, 1994; Knox, 1985).

3.3.4.2 Other Trace Elements.

The effects of fluoride on caries have been investigated thoroughly, but there are other trace elements that appear to have an impact on caries prevalence. However, the extent of their influence is less well understood. Molybdenum (Mo) is one of the elements believed to protect against dental caries. Research into the caries experience of North American Navy recruits noted that the origins of recruits with no caries experience clustered in certain areas of the United States (Losee and Adkins, 1969). Investigation of the water supplies in these areas recorded high levels of molybdenum and strontium, and it was also noted that the inhabitants of the areas in question favoured consumption of dark, leafy vegetables (beet greens, turnip greens, mustard greens and collards) that contain much higher levels of molybdenum and strontium than the vegetables preferred by the control areas. Similar low levels of caries were observed in children from an area of Britain (Somerset) that contained high levels of molybdenum in the soil (Anderson, 1969). Although his results were not conclusive, he suggests that milk was more important than water as a source of molybdenum, and that the levels in milk were related to the levels of molybdenum found in the grass on which dairy herds were pastured. Higher levels of molybdenum were found in the grass in the molybdenum area compared to the control area, although the effect might be diluted as only c. 60% of the milk produced in the molybdenum area was consumed there. Losee and Ludwig (1970) review several other studies of the relationship between molybdenum and caries that displayed similar results, but caution that not enough is known about the effects of the interactions between trace elements and it is likely that molybdenum is not the sole factor at work. They also observe that not all studies have demonstrated a difference between areas of high and low molybdenum in relation to dental caries. Other trace elements that may exert a preventive effect on dental caries include vanadium (V), strontium (Sr), phosphorous (P), copper (Cu), calcium (Ca), magnesium (Mg), boron (B), and aluminium (Al) (Losee and Ludwig, 1970).

Not all trace elements are beneficial; some may promote the development of carious lesions. One of the most frequent symptoms of selenium toxicity is a high prevalence of dental caries, and although some studies show a direct correlation between the two (Hadjimarkos, 1969), others have not found a definite relationship (Nixon and Myers, 1970). Selenium is believed to alter the tooth structure during development making it more vulnerable to developing caries (Luoma, *et al.*, 1971). As with molybdenum, the levels of selenium in the food were considered to be a more important source of the element than the levels in water (Hadjimarkos, 1969). Other trace elements that encourage dental caries may include beryllium (Be), lead (Pb), iron (Fe), manganese (Mn), and potassium (K).

Regional differences in caries prevalence have been associated with variation in soil or climatic conditions (Ludwig and Bibby, 1969). Trace elements in the soil are incorporated into plants, depending on the type of plant, climatic conditions and the amount of different trace elements in the soil (Losee and Ludwig, 1970). In turn, the concentration of trace elements in animals, and animal produce such as milk, depends on the levels present in the plants they eat. Usually higher levels of the trace elements are found in the organs rather than in the muscle and fat (Losee and Ludwig, 1970). Studies of the selenium and molybdenum content of soils in Britain have shown that concentrations of these elements do vary in the UK (Webb, *et al.*, 1966). However, the levels of trace elements in plants do not reflect the absolute levels in the soil as there are many factors governing trace element uptake (Hadjimarkos, 1969). In addition, there is evidence to suggest that different food groups consistently contain higher or lower quantities of certain trace elements than other food groups, so the availability and choice of food is important in determining trace element exposure (Losee and Ludwig, 1970). Methods of food preparation will also affect the trace element content of the food, as some elements are lost and some gained when food is cooked in water (Losee and Adkins, 1969).

3.3.5 Summary.

From the discussion above it can be appreciated that there are a multitude of complex and interrelated factors that influence the development of dental caries. This section provides a brief summary of the main points.

Sugar is associated with high caries prevalence, but its cariogenicity is modified by a variety of factors. Sucrose is probably the most cariogenic, and lactose the least cariogenic of the sugars. Intrinsic sugars (found in the cells of fruits and vegetables) and milk sugars (lactose) are not as dangerous as the non-milk extrinsic sugars. The latter occur in honey, fruit juices, dried fruits, and (usually in the form of refined sucrose) can be added to food at all stages of processing, preparation and before consumption. Starch on its own is not particularly cariogenic, especially if raw or unrefined, but its cariogenicity increases if it is refined, processed or cooked, or if it remains in contact with the teeth for a long period of time. Starch combined with sugar is a dangerous blend, and foods containing both, such as cakes and biscuits or bread and jam, place the teeth at higher risk. Refined sugar and starch are more cariogenic than unrefined sugars and starches. The frequency with which cariogenic foods are eaten is probably as important as the amount consumed; the more often they are eaten then the greater the risk to the teeth. The texture of the food is also important, as sticky foods adhere to the teeth and can remain in the mouth for a long period of time.

Some foods exhibit a protective effect, especially cheese and milk. Cheese is effective eaten at the end of a meal, but has also demonstrated beneficial effects even if cooked and consumed during a meal. Fluoride is a trace element that has demonstrated clear anticariogenic properties. Its concentration in water supplies varies, but it needs to be present above a level of c. 0.7 ppm to exert a definite benefit. It is also present in marine foods, and regular consumption could prove beneficial to teeth. Other trace elements may also influence caries development, but their role is less understood and the strength of their influence is probably less than that of fluoride.

Cultural and economic factors will determine the type of foods available, at the general level and at the level of specific groups of individuals. They will also influence the way in which food is processed for storage or consumption, and patterns of consumption (who eats what and when), each of which may modify the cariogenic potential of the foods in question. Cultural factors will govern the type of oral hygiene practiced, if any, and influence the groups of individuals that are likely to engage in this behaviour. Variation between individuals in terms of physiological factors will have a bearing on the caries experience of that individual, as will any variations in individual behaviour that affect food choice or oral hygiene measures.

3.4 The Palaeopathology of Dental Caries.

This section discusses some of the studies that have been conducted on caries prevalence in archaeological populations, both in Britain and elsewhere. However, firstly the main ways in which caries prevalence is compared between populations are outlined. In clinical studies the mean number of decayed, missing and filled teeth (DMFT) or tooth surfaces (DMFS) per person is often used as the basis for comparison (Hillson, 2001). This method is not appropriate for archaeological populations as it assumes that all missing teeth are missing due to caries. In archaeological populations many teeth may be missing due to postmortem loss, and there are other aetiological factors behind ante-mortem tooth loss apart from caries, such as periodontal disease or pulp exposure through heavy attrition. In addition, filled teeth are rarely encountered in most archaeological populations (Hillson, 2001; O'Sullivan, *et al.*, 1993). Some studies on archaeological populations have used a variation of this method, whereby the total decayed and missing teeth (DM Index) are expressed as a percentage of the observable teeth and repaired tooth sockets present in each individual, and the average obtained for the population (Saunders, *et al.*, 1997; Sutter, 1995). However, this still assumes that the missing teeth had carious lesions.

In archaeological material one of the biggest problems in expressing caries prevalence is dealing with missing teeth; if teeth are missing then it is impossible to know whether or not they had a carious lesion. This fact complicates the calculation of caries prevalence as the proportion of individuals affected, as most archaeological skeletons have incomplete dentitions, with teeth lost both postmortem and ante-mortem. If an individual had caries in life but the tooth (or teeth) affected is lost either before or after death, then the skeleton examined will not be included in the count of individuals with caries and caries prevalence is underestimated (Roberts and Manchester, 1995). In an attempt to deal with missing teeth, studies of many archaeological populations have expressed caries prevalence as the number of teeth with caries as a proportion of the number of teeth present for observation. However, there are problems with this method as the teeth most commonly lost postmortem are the single-rooted anterior teeth, but the teeth most often affected by caries are the posterior teeth, with their larger surface area and more complex crown morphology (Hillson, 2001). This differential tooth loss and variable susceptibility to caries will act to inflate caries prevalence. Conversely, caries is one of the main aetiological factors implicated in ante-mortem tooth loss, so in populations where a large number of teeth have been lost ante-mortem the caries prevalence calculated using this method is likely to be an underestimate (Hillson, 2001).

A possible solution is to record prevalence by each tooth type, which compensates for the differential loss of teeth and variations in susceptibility to some extent. However, although several studies of caries prevalence have used this method, not many standard skeletal reports have done so. Some researchers have attempted to correct the caries prevalence by estimating the number of carious teeth amongst those lost ante-mortem, using this figure to adjust the prevalence rate. Hardwick (1960) simply assumed that with increasing caries prevalence, the proportion of teeth lost ante-mortem due to caries would rise at a fixed rate. Brothwell (1963) objects to this practice as there is evidence that the aetiology of ante-mortem tooth loss in ancient populations has changed through time, and probably varied between populations. Lukacs (1995) devised a more sophisticated method that tried to estimate the proportion of teeth lost ante-mortem due to caries on the basis of trends in ante-mortem tooth loss specific to the population under study. In addition, Erdal and Duyar (1999) have designed a correction factor to take account of postmortem tooth loss, suggesting it is applied after Lukacs' ante-mortem correction factor. However, Kerr *et al.* (1990: p73) have commented that "such adjustments can in fact mask important differences between populations", and Hillson (2001: p257) makes the point that these calculations "make assumptions which are difficult to test" and do not address many of the problems inherent to reporting caries prevalence in archaeological populations.

Another important issue that must be addressed is age. Caries, being a progressive disease that occurs in non-repairing tissues, increases in prevalence with age (Hillson, 2001). Therefore, differences in caries prevalence can reasonably be expected where two populations with different age profiles are compared, even if they are identical in all other respects. The younger population will have a lower caries prevalence rate than the population containing more of the older individuals. Many of the methods outlined above, on their own, do not take account of age differences in populations. One method whereby this issue can be addressed is to compare caries prevalence (for teeth, tooth type, or individuals) by age groups. However, the accuracy of ageing methods in archaeological skeletons has been questioned for many years, (for example, Powers, 1962; Murray and Murray, 1991; Molleson and Cox, 1993; Key, *et al.*, 1994; Molleson, 1995), and even assigning individuals to broad age categories can be difficult. When attempting to compare data from different studies the variation in aging method used, reliability of the age estimates, and different choice of age categories into which the data are grouped are all factors that hinder useful comparison. Although many studies specifically on dental disease have accounted for age differences in populations, most skeletal reports do not present data on dental caries by age category.

Another problem arising from the above issues relates to sample size. If more and more sub-divisions of the sample are required to account for age, sex, tooth type etc. then samples can quickly become too small for any but the most tentative of conclusions to be drawn. However, in view of these limitations and variations in data presentation, some of the studies of dental caries in archaeological populations are discussed below.

3.4.1 Worldwide Caries Prevalence.

Studies on caries prevalence have been conducted on many samples from all time periods from all over the world. Many have used the evidence provided by caries combined with other dental and skeletal pathological conditions to contribute to debates on the diet and subsistence strategies of past populations. Increases in the prevalence of dental caries have frequently been used as evidence of the adoption of agriculture or agricultural intensification. Turner (1979) compiled data from a variety of published sources from around the world, both archaeological and ethnographical, to provide an indication of the usual caries prevalence in the permanent teeth encountered in populations practicing hunting and gathering (1.72%), a mixed economy (4.37%) and agriculture (8.56%). The low prevalence in hunter-gatherers was attributed to the high-protein, low-carbohydrate diet, with the high prevalence in agriculturalists ascribed to the lower levels of protein available and the high proportion of processed carbohydrates typically consumed by farmers. Turner compared the data from a Japanese population dating to the Late Jomon Period (c. 1000 BC) with these figures, finding that their caries prevalence of 8.6% strongly suggested that these people were consuming large amounts of carbohydrates, and therefore were practicing agriculture.

Larsen (1995) has reviewed biological evidence from all over the world concerning the transition to agriculture and found that, although not all hunter-gatherer groups have a low caries prevalence, an increase in dental caries occurs repeatedly with the adoption of agriculture, and that increased carbohydrate consumption is the likely cause. Stable isotope analysis of archaeological populations from the Georgia Bight have shown that there was an increase in maize consumption in the period AD 1150-1300 (Larsen, *et al.*, 1992). The caries prevalence in the permanent teeth for this period was 11.4%, compared with 1.3% of the preceding period, and this increase in caries was associated with the increased reliance on maize. The shift towards maize consumption occurred later in Florida, after European contact, according to isotopic analysis, and again there was a dramatic increase in caries prevalence in the post-contact sample (Hutchinson, *et al.*, 1998). Increased caries prevalence in association with intensification of agriculture was noted in populations from the Indus Valley, South Asia (Lukacs, 1992), and in Nubia (Beckett and Lovell, 1994). In the latter case, although both groups appeared to be practicing a mixed economy, the higher caries prevalence in the later group suggested that they were relying more heavily on carbohydrate-rich agricultural produce, which implied agricultural intensification. Hillson (1979) observed an increase in caries prevalence through time in Nubian and Egyptian populations. These changes could be related to a change towards a diet higher in carbohydrates and lower in protein, but he states that it is possible that other factors were influential.

Studies of later populations have tended to show a continued increase in caries prevalence. Caries prevalence in historic populations from Quito, Ecuador (AD 1524-1940) showed little change from pre-contact levels until the late seventeenth/early eighteenth centuries, when they increased dramatically (Ubelaker, 1995). This rise was attributed to increased dietary intake of refined sugar when it became more economically accessible. In seventeenth century Göteborg, Sweden, 11.6% of permanent teeth had caries (Lingström and Borrman, 1999). Less sugar was available than that consumed by modern populations, and the caries prevalence is explained as being the result of the total intake of fermentable carbohydrates. Saunders *et al.* (1997) report a high caries prevalence rate (31.1% of the permanent teeth) for a nineteenth century population in eastern Canada. They also investigated carbon isotope values, and found a weak trend for increased carbon ratios through time, which they tentatively attribute to increased sugar consumption, as there is no evidence for increased maize consumption. There is much historical evidence for increased availability of sugar in this time period, and this is likely to have contributed in part to the high caries prevalence observed in this population. Other contributing factors cited include food preparation method, food consistency, and frequency of eating.

3.4.2 Caries Prevalence in Britain.

Various studies have examined caries prevalence in British archaeological populations, several looking at changes through time in relation to diet. Some of the earlier attempts were hampered by lack of suitable data, as excavated human skeletal remains that could be studied were not easy to obtain. Drummond and Wilbraham (1957: p 164) encountered this problem: "We can get a little evidence about the state of the teeth in England at different periods by examining skulls which can be dated with some certainty, but, unfortunately, there is not a great deal of this material available". They refer to material dating to c. AD 1250-1650 from St Leonard's Church, Hythe but since data on actual numbers of teeth present and teeth with caries were not collected, the only statement they could make is that caries "was a good deal less prevalent than it is today" (1957: p164). They also report data on Post-Medieval skeletal remains examined by Sir Frank Coyler, which suggested that roughly 10% of teeth were carious.

In 1959, Brothwell published a paper examining changes in caries prevalence in early human populations from the Palaeolithic through to the present, with a focus on Britain from the Neolithic onwards. He observed an increase in caries from the Iron Age to the Roman period, a decrease during the Anglo-Saxon period, with a subsequent increase from the Late Medieval period onwards. The latter was attributed to the introduction of sugar in the twelfth century, with later increases due to the introduction of refined white flour in the nineteenth century. Hardwick (1960) includes a table of caries prevalence for skulls from different periods based on data collected from other published sources. He provides prevalence rates for two groups of material from the Early Medieval period, which combined have a sample size of 2694 teeth: the 'Saxon' group had a caries prevalence rate of 5.6% and the 'Anglo-

Saxon' group a prevalence of 8.1% (both prevalence rates are based solely on the teeth present and exclude estimated values). No data for the Medieval period are included in this table, as none were available, but general reference is made in the text to the St Leonard's material mentioned above. These Early Medieval prevalence rates are described as being unusually low in comparison to both the preceding Romano-British period (11.4%) and the later Post-Medieval period, where three sources of data give prevalence rates of 16.7%, 19.7% and 9.7%. The low caries prevalence in the Anglo-Saxon period is attributed to the coarse texture of the food, which contained little soluble material, and the lack of refined sugar, whereas the increase observed in the Medieval period is related to the introduction of refined sugar in the twelfth century.

A detailed and thorough study of caries prevalence in archaeological populations in Britain was carried out by Moore and Corbett and published in a series of papers during the 1970s (Moore and Corbett, 1971, 1973, 1975; Corbett and Moore, 1976). In an effort to redress the lack of data then available, particularly for certain time periods, and to gain a clearer picture of changes in caries prevalence through time, they recorded caries in a series of populations from the Iron Age, Romano-British, Anglo-Saxon, and Medieval periods, and the seventeenth and nineteenth centuries. Data on which teeth were affected, the location of the lesion on the tooth, and the age of the individual were collected. The actual numbers of teeth within each sample are not given, but the number of dentitions involved was 504 for the Anglo-Saxon period and 416 for the Medieval period. The Anglo-Saxon sample mainly came from pagan Anglo-Saxon cemeteries from a variety of locations across the middle, south and east of England. Much of the Medieval sample came from village or town communities, but a small proportion came from the burial grounds of religious houses. Rather than express caries prevalence for each sample as the total number of teeth with caries as a percentage of the total teeth present, they calculated the caries prevalence for each tooth type for each individual, and from these data derived the mean caries prevalence for each tooth type for each age group within each period. For this reason, the results they obtained are not directly comparable with those of the other studies discussed here. However, they noted that there was a tendency for the Saxon population to have a lower caries prevalence rate than either the preceding Romano-British or succeeding Medieval period, and that this difference was significant for some age groups and tooth types. Aside from this there were no significant changes in the pattern of caries prevalence from the Iron Age through to the Medieval period. Again, the coarse, starchy Anglo-Saxon diet lacking in sugars is cited as the cause of their low caries prevalence, with the coarse consistency of the food acting to cleanse the teeth.

There have been several studies carried out on caries prevalence in skeletal material from Medieval Scotland. Lunt (1986) compared skeletons excavated from St. Mary's Church, Kirkhill, St. Andrews (twelfth to sixteenth centuries AD) with burials from Hallowhill, St Andrews (sixth to ninth centuries AD), and with data compiled from other early (sixth to eleventh century) and late (twelfth to sixteenth century) Medieval Scottish sites. She found that the caries prevalence rates in the permanent teeth for Hallow Hill (2.84%) and the Early Medieval sites (4.32%) were fairly low compared to the Later Medieval prevalence of 6.00% and the Kirkhill prevalence of 6.84%. When the Kirkhill and Hallow Hill populations were compared by age group, an increase in caries prevalence was found from the earlier to the later population within each age group. Kerr *et al.* (1990) compare the caries prevalence in the human remains excavated from Linlithgow Carmelite Friary with the data from Aberdeen Carmelite Friary and other Medieval Scottish samples. They conclude that Scottish populations generally had a lower caries prevalence than English populations.

An investigation of dental disease in Ireland from the Neolithic to the Early Medieval period reported that 3.9% of the Early Medieval permanent teeth were carious compared to 4.4% of the Iron Age teeth (Power, 1993).

A recent study of dental disease in skeletal material from seven archaeological sites dating from the Romano-British to the Medieval periods observed that caries prevalence was lowest in the pooled Anglo-Saxon sample (7.2%), having dropped from 10.3% in the Romano-British period, and rose to 11.5% in the Medieval period (Freeth, 1999). She attributes the low caries prevalence in the Anglo-Saxon period to the lack of cariogenic foodstuffs rather than to the coarse texture of the diet, which, she argues, has been overemphasised as an aetiological factor.

Since the 1950s and 1960s, when the earlier of these studies were written, a large number of cemeteries have been excavated and the skeletal material analysed, meaning that sources of data have increased dramatically. Roberts and Manchester

(1995) include a table collating some of the data from these skeletal reports, which lists caries prevalence in several archaeological sites for the Romano-British, Anglo-Saxon, Medieval and Post-Medieval periods. As was the case with the earlier studies, they observe that caries prevalence rates in the Anglo-Saxon sites tend to be lower than those in the Romano-British or Medieval/Post-Medieval sites. A more recent and comprehensive compilation of data is provided by Roberts and Cox (2003), although it is unclear whether the caries prevalence rates given for each site refer to all permanent teeth or just those from adults. For the Early Medieval period they report an overall prevalence rate of 4.2% (based on data from 36 sites), and for the Late Medieval period an overall prevalence of 5.55% (based on data from 27 sites) is given. These figures can be compared with a prevalence rate of 7.5% (based on data from 29 sites) for the Romano-British period, and 11.22% (based on data from nine sites) for the Post-Medieval period.

Most of the studies of caries prevalence in Britain have concentrated on adults, or permanent teeth. Few studies have investigated the caries experience of children (a fact noted by O'Sullivan, *et al.*, 1992; 1993; Williams and Curzon, 1986). In the study of Medieval Scottish dentitions discussed above, Lunt (1986) observed that caries was absent from the Hallowhill and Early Medieval deciduous teeth, but was present in deciduous teeth from Kirkhill and some of the teeth from the Later Medieval period. Williams and Curzon (1986) studied a small group of British Medieval children and noted a pattern of caries similar to modern nursing caries. They suggest that this is related to the diet and feeding habits of Medieval children. The diet of young children in the Medieval period consisted of human breast-milk, cows' milk, pap consisting of flour or bread boiled in water with added flavouring (spices, beer, wines, herbs, honey), or milk thickened with breadcrumbs; oatmeal was possibly consumed in northern Britain. A 'sucking bag', filled with bread, milk, flour water, or unfermented meal or porridge, was frequently used to pacify children, and the child was often allowed to sleep with it. Both these studies focussed on the Medieval period, but the study conducted by O'Sullivan *et al.* (1993) examined caries prevalence in deciduous molars from c. 3000 BC to the eighteenth century, showing that caries prevalence in subadults from the Anglo-Saxon period was significantly lower than in the Romano-British or Medieval periods. The Early (fifth to sixth centuries) and Late (ninth to eleventh centuries) Anglo-Saxon samples had a prevalence rate of 7% and 6%

respectively, compared to 16% for the Romano British sample (AD 60-410), 11% for the Early Medieval (eleventh to twelfth centuries), and 23% for the Late Medieval (thirteenth to fifteenth centuries) periods. This trend reflects that observed in adult teeth.

In all of these studies of caries prevalence in Britain through time a similar pattern emerges, for both adult and subadult dentitions. The prevalence rate in the Anglo-Saxon/Early Medieval period is invariably lower than the rate present in the Romano-British period, with an increase observed from the Anglo-Saxon/Early Medieval to the Late Medieval period. It is not just the overall caries prevalence that has changed; many studies have reported a shift in the location of the lesions on the tooth surface. In studies of modern populations the crown of the tooth is more frequently affected by caries in children and younger adults, but remains a common site of caries in older adults. Caries of the root surfaces is rare in younger individuals, but becomes more common in older age groups (Hillson, 2001). In archaeological populations, however, the most common site of carious attack tends to be the cemento-enamel junction (CEJ), where the crown meets the root. Hardwick (1960) observed an extremely low occurrence of fissure caries in the Anglo-Saxon populations examined, with most of the carious lesions occurring at the CEJ, a fact also noted by Brothwell (1959). Moore and Corbett (Moore and Corbett, 1971, 1973, 1975; Corbett and Moore, 1976) found that the CEJ was the site most commonly affected by caries from the Iron Age to the Medieval period, especially at the interstitial surfaces, with lesions rarely occurring in the fissures or contact areas between the teeth, although occlusal caries was more commonly observed in the younger age groups. The rarity of fissure caries was attributed to the lack of sugar in the diet, in conjunction with the heavy attrition of the teeth. They hypothesise that the accumulation of food around the necks of the teeth led to the development of caries at the CEJ. They observed an increase in caries at the contact areas between teeth in the Medieval period, which, along with caries of the occlusal fissures, increased considerably by the seventeenth century. This trend continued in the nineteenth century, accompanied by an overall rise in caries prevalence. Freeth (1999) also found that the CEJ and the root surfaces were most frequently affected in the Romano-British and Anglo-Saxon populations, but that an increased number of lesions occurred in the non-occlusal surfaces of the tooth crowns in the Medieval period. In an examination of the prevalence of root caries in a sample from Linlithgow Carmelite Friary, Scotland, Kerr (1990) observed an increase in root caries with age, the most common location being at the approximal surfaces of the CEJ. He suggests that the buccal and lingual surfaces were protected by heavy calculus deposits. O'Sullivan *et al.* (1993) observed the same trend apparent in the adult dentition in the deciduous dentitions they studied, with most carious lesions initiated at the CEJ in all periods except the seventeenth and eighteenth centuries.

3.4.3 Fluoride.

The effect of fluoride on caries prevalence in archaeological populations has not often been investigated. The presence of fluoride in water supplies as a factor in caries aetiology has been mentioned in a few studies (for example Larsen, 1995), but has usually not been studied in its own right. One of the few studies that has related caries experience to water fluoride levels is that conducted by Blau *et al.* (2002). They looked at variations in dental health in archaeological skeletal remains from the United Arab Emirates, an area that today has fluoride levels of up to 8 ppm in some areas. They discovered a high degree of dental fluorosis, and suggested the possibility that lower caries in southern sites compared to the northern sites could be related to higher fluoride in the natural water supplies, but that more detail on the specific fluoride values associated with each of the sites studied was needed to clarify the situation. Littleton (1999) discusses the possibility that fluoride levels in the water resulted in skeletal fluorosis in skeletal material from Bahrain, ~~Arabian~~ Persian Gulf (250 BC – AD 250), but there is no mention of the caries prevalence in these populations.

Studies of prehistoric populations in Georgia have tended to observe lower caries prevalence in coastal sites compared to inland ones (Larsen, *et al.*, 1992; Larsen, 2000). Isotopic analysis has confirmed that more marine foods were consumed at the coastal locations, but the low caries prevalence is attributed to the fact that more protein in general was consumed, without reference to the high fluoride content of marine-based food, and that carbohydrates made up a higher proportion of the diet in the inland sites. Likewise, the change from a low caries prevalence of 1.3% to a high prevalence of 11.4% is related solely to the adoption of maize agriculture, without considering the fact that the high marine base of the earlier diet was probably contributing to the low prevalence rate (Larsen, *et al.*, 1992). A study of Maya populations in Mesoamerica also discovered a low caries rate associated with coastal sites, where marine resources made up a large proportion of the diet (Storey, *et al.*, 2002), yet again the difference is attributed solely to high carbohydrate consumption in the inland rural sites. Littleton and Frohlich (1993) conducted a study of populations in the Arabian Gulf. The results are complex, but the coastal population highly dependent on marine foods had very low caries prevalence, and low caries rates were also observed in some offshore island sites practicing a mixed economy with some dependence on marine foods. Interestingly, fluoride was only mentioned in connection with the water supply, and the low caries prevalence at sites with a marine-based diet was interpreted to reflect a low intake of carbohydrates. The inland sites and the remaining offshore island sites both had high caries prevalence. Both groups of sites were probably involved in intensive date farming, consuming some grain, fruits and vegetables, and a little fish. Date consumption was also linked to extremely high caries rates (18.4%) observed in Iron Age Oman (100 BC – AD 893) (Nelson, *et al.*, 1999).

In contrast, other studies observing a difference in caries prevalence between populations reliant on marine resources and those dependent on plant carbohydrates have related this to the fluoride content of sea foods. Walker (1986) observed a decrease in caries prevalence in the skeletal material from Santa Rosa Island, California between 4000-400 BP, which was associated with a shift from a diet based on plant roots and tubers to a high-protein marine diet. Being both high in protein and rich in fluoride, the latter diet exerted a protective effect and reduced caries prevalence. He even proposes that the smaller tooth size evident in the later populations might be related to the increased fluoride consumption. Fooce and Sciulli (2003) found that populations where domesticated plants made up a large portion of the diet had a higher caries prevalence than those populations not relying on domesticated plants, but that "coastal populations, regardless of subsistence base, express lower prevalences of dental disease than non-coastal populations". The lower caries prevalence in coastal populations was attributed to the marine diet. When comparing the caries prevalence of Jomonese skeletal remains with that of Chinese skeletal remains, Turner (1979) commented that the Chinese prevalence could have been lowered by the drinking of teas, but that the Jomonese might also be receiving large amounts of fluoride in the marine produce they consumed.

Fluoride is not mentioned often in relation to the dental health of British skeletal remains, as there are few areas of Britain with a naturally occurring high level of fluoride in water supplies. Of more than 33,000 samples of natural ground water taken across Britain, only around 0.6% had levels of fluoride exceeding 0.7 ppm, and even fewer (0.05%) exceeded 2.0 ppm (Barry Rawlins, British Geological Society, *pers. comm.*). The very high levels occur mainly in the north east of England, as is shown on the maps published annually by the Department of the Environment (1998). Marlow (1986) reports that most natural fluoride levels in Hartlepool are 2.0 ppm, and reports a caries prevalence of 6.1% for the skeletons excavated from the Franciscan Friary. The fluoride levels in South Shields are also reasonably high, at 0.7 ppm (Marlow, 1986), but the low caries prevalence rates seen at Jarrow and Monkwearmouth were suggested to be the result of "copious fish eat[ing]" (Wells, 2000: p48). Mays (1997) also briefly discusses the fluoride content of seafood and its potential to have reduced caries prevalence in British monastic samples. Aside from a few isolated remarks such as these, there is little reference to the potential role of fluoride in affecting caries prevalence in British material. One of the problems is that data relating to fluoride levels in historical times are lacking, and although modern data can be used as a substitute, human activity, such as aluminium smelting, manufacturing of brick, glass and ceramics, artificial water fluoridation and the use of phosphate fertilizers, can raise fluoride levels (Camargo, 2003), and so they may not be representative of past levels.

3.4.4 Sex Differences in Caries Prevalence.

Several studies of caries in archaeological populations have not investigated any differences in prevalence between the sexes (for example, Lingström and Borrman, 1999; Power, 1993; Kerr, 1990; Kerr, *et al.*, 1990; Lunt, 1986), and others do not discuss the differences in caries prevalence present (for example, Sakashita, *et al.*, 1997; Owsley, *et al.*, 1987; Pechenkina, *et al.*, 2002; Turner, 1979; Beckett and Lovell, 1994). This is puzzling, as a considerable number of studies have observed differences in caries prevalence between the sexes, and it is invariably females that have the higher prevalence rate.

The majority of clinical studies conducted have found a higher caries prevalence in females, with Antunes *et al.* (2003: p231) reporting that "quantitative reports of the higher prevalence of dental caries in females is not new." In their study of urban Brazilian children, they observed that girls had higher caries prevalence than boys, and that this discrepancy was still present even after DMFT scores were adjusted to account for the earlier eruption of teeth in the girls. However, they still suggest that most of the difference in caries prevalence between girls and boys is due to the fact that the permanent teeth erupt earlier in girls than in boys. Åstrøm and Haugejorden (2000) comment that although, in general, caries prevalence is low and has remained stable in Sub-Saharan Africa, females and urban populations have experienced an increase in caries compared to males and poor rural populations. They report that females tended to consume more sugared snacks (chocolate/sweets, sugared tea/coffee, soda) than did the males, and that the difference between the sexes was more pronounced in the urban than the rural areas. A similar pattern of consumption was also noted by Okullo *et al.* (2003) amongst Ugandan children, where again sugar consumption was higher in females and children of highly educated parents. Such behaviour would place females at greater risk of developing caries, although Åstrøm and Haugejorden (2000) also report that females are more likely than males to practice regular oral hygiene, which is likely to reduce their risk of caries to some extent. During the Vipeholm study, the females in the group with unrestrained access to toffees were found to consume far more toffees than the males, and consequently developed more carious lesions (Moynihan, 2003). Not all clinical studies have found a higher caries prevalence in females. In a study of Australian aboriginal populations, Slater (2001) found that males seemed to have more caries. However, the focus of her study was on treatment patterns, and treatment could reflect things like attitude to disease, willingness to attend dental clinics etc., and these cultural factors might well vary by sex.

A few studies have suggested that there are physiological differences between males and females that place females at increased risk of caries development. In a study of salivary composition and flow rate, Mazengo *et al.* (1994) found that males tended to have a higher salivary buffer effect than females, i.e. their salivary pH was higher and better able to protect the teeth against episodes of demineralisation. They also observed that the group of individuals (including both males and females) with the higher buffer effect had a higher intake of fibrous foods (requiring more chewing) than the group with the lower buffer effect, and that the difference was significant for females but not for males. Essentially, females consuming fibrous foods were likely to experience a greater increase in salivary buffering than males. In addition, Mazengo *et al.* noted that females had lower salivary calcium, but higher phosphate, concentrations than males. A lower concentration of these ions would increase the risk of caries development, so the lower calcium would be detrimental to the health of the teeth, but the higher phosphate would be beneficial. They also comment that females had a slightly lower salivary flow rate than did males, but this difference was found not to be significant. Low salivary flow rates are not as effective at clearing food debris from the mouth, or delivering calcium and phosphate ions to the tooth surfaces, and prolong the depression in pH associated with the consumption of fermentable carbohydrate.

Hormonal changes related to pregnancy and, to a lesser extent, the menstrual cycle both alter salivary composition in a way that may induce the development of dental caries. Decreased salivary flow rates and lower pH levels have been reported during pregnancy: Salvolini *et al.* (1998) found that the capacity of saliva to buffer against drops in pH level was at its lowest during the third trimester of pregnancy. They also found a significant decrease of both calcium and phosphorous ions in the saliva in pregnant women compared to the non-pregnant controls, which is probably related to the requirements of the growing foetus. All these factors would act to enhance the development of caries, although they did observe an increase in the sialic acid content of the saliva, which would encourage clearance of the bacteria from the mouth and so help protect the teeth.

A few studies of archaeological material have shown a higher caries prevalence in males, for example prehistoric populations in Thailand (Tayles, *et al.*, 2000). However, as with clinical studies, the majority of palaeopathological investigations have shown that females usually have higher caries prevalence than males. Hillson (1979) suggested that the higher female caries prevalence for all four types of caries recorded in Ancient Egyptian and Nubian populations was possibly due to a higher consumption of sugar amongst females, or to physiological differences. In a report on a nineteenth century Canadian population, Saunders *et al.* (1997: p85) attribute the higher caries prevalence seen in teeth from females (41.0%, compared to 30.9% for the males) in part to women's "usual role in food preparation and their continuous access to food throughout the day". In an overview of health in North America, Larsen (2000) observes that, time and again, females had a higher caries prevalence than males, from prehistoric Native American populations at the transition to agriculture to seventeenth and nineteenth century European settlers. In all cases he ascribes this difference to sex divisions in labour, giving women more contact with cariogenic plant foods, especially corn, and males more access to protein foods.

Cucina and Tiesler (2003) observed sex and status differences in caries prevalence in Mayan populations. No significant differences in caries prevalence were observed between the sexes in the low status group (males = 6.3%, females = 6.9%), or between the caries prevalence of low and high status females (8.8%). However, the high status males had a caries prevalence of 1.4%, significantly lower than both the high status females and the low status males. They suggest that the low status individuals were reliant on high carbohydrate foods with minimal protein in the diet, with the high status females also restricted in protein consumption, but that the high status males enjoyed a protein-rich diet with fewer carbohydrates. They also observe that:

> "...women who are restricted to household activities tend to eat more frequently during the day, while preparing the food for the family or performing their daily household activities. In turn, males, who leave the house to engage in field labour, eat the same kind of food in more restricted schedules than their spouses, thus reducing the possibility for food residuals to remain in the mouth, and consequently shortening the time of exposure to bacterial reactions" (Cucina and Tiesler, 2003: p7).

In a review of health at the transition to agriculture, Larsen (1995: p189) observed that the increase in caries normally found with agricultural populations was usually greater in females than in males, suggesting that this indicates "widespread gender-based differences in preparation and consumption of food". In addition he postulates females are more at risk of dental caries than males when consuming a high-carbohydrate, low-protein diet. Beckett and Lovell (1994), in their study of agricultural intensification in Nubia, presented data showing that caries prevalence in the earlier population was similar between the sexes (males = 2.4%, females = 3.3%), but that in the later period caries had increased in the females (9.3%) more than in the males (6.3%). However, they do not discuss these differences and pool the data for further analysis between the two populations.

In his study of populations from the Northern Channel Islands, California, where the opposite transition is made from a carbohydrate-based to a marine-based diet, Walker (1986) observed that females had far more caries than males in the earlier populations, but that after the transition to a marine-based diet and a reduction in overall caries prevalence, the caries prevalence was the same for both sexes. The earlier sex-difference is suggested to represent a sex-division in labour, resulting in differential access to foods. He cites the example of the Chumash Indians, where men specialised in hunting and fishing and the women gathered plant foods, noting that the men were in the habit of consuming some of their catch before bringing it back to the rest of the group. Such behaviour gives males more access to protein, and so the females tend to consume more carbohydrates. He surmises that "while the Canada Verde women may have had equal or greater access to shellfish than men, these are generally lower in protein, fat and fluoride content than sea-mammal meat and fish, characteristics that would result in a higher caries rate among women" (Walker, 1986: p360). A similar conclusion is drawn by Lukacs (1992), who also observed a higher caries prevalence among females in a South Asian population. In this study, marked differences in the pattern of teeth affected by carious lesions were observed between males and females: none of the male anterior teeth were affected compared to high frequencies of the female anterior teeth with caries. He suggests that this reflects a "gender based division of labour", which "is often accompanied by significant differences in diet between the sexes" for both hunter-gatherers and farmers (Lukacs, 1992: p143). Like Walker, he notes that men tend to consume meat whilst hunting and, in general, eat less often than do women. In contrast, women have more access to cariogenic foods, and tend to eat more frequently throughout the day. He also concludes that the male South Asians hunted and consumed more protein foods than did the females. Turner (1979) also observed striking differences in the teeth affected by caries between males and females in the Jomon population, where again females were found to have a high caries prevalence in the anterior teeth whilst these teeth were unaffected in the males. However, these differences were not found to be significant, and the data is pooled without further discussion.

The tendency for females to have higher caries prevalence than males therefore occurs in both the clinical and palaeopathological literature. The reasons for this difference may in part be due to physiological differences between the sexes, meaning females are more vulnerable to developing carious lesions. Differences in behaviour are also implicated, with females tending to eat more cariogenic foods than males, either through choice, as in the clinical studies where sugary foods are chosen more often by females, or as a result of culturally defined gender roles, such as differential labour divisions placing females in a position where they have greater access to cariogenic carbohydrate foods but are restricted in their consumption of protein foods. Females also seem to have a tendency to consume food more often, which is probably linked to their usual role in food preparation, cooking and childcare.

3.4.5 Status and Caries Prevalence.

Caries experience in modern Western countries is high, although recent years have seen a declining trend in caries prevalence. This change has been associated with the introduction of water fluoridation, improved oral hygiene, education, and dental health care rather than with changes in sugar consumption (Ettinger, 1999; Gray, *et al.*, 1970; Woodward and Walker, 1994; Marthaler, 1990; Marthaler, *et al.*, 1996). In these countries, high caries prevalence tends to be found among groups of low socio-economic status (Levine, 2001; Rugg-Gunn, 2001). For example, in North America 50% of all carious teeth are found in 12% of children, and it was noted that children from low-income households were more likely to have caries than those from high-income households (Ettinger, 1999). Different patterns of food consumption (Ministry of Agriculture, *et al.*, 1994), attitudes towards oral hygiene and dentistry may all contribute to the trend (Fabian Society, 1975; Kelly, *et al.*, 2000). Low socio-economic groups in Australia had a tendency for poor oral health and low attendance for dental care, which was predominantly sought for emergency rather than preventive treatment (Slater, 2001), and differential access to dental care was also found between groups of differing socio-economic status in Brazil (Antunes, *et al.*, 2003).

However, in recently industrialised and developing countries the trend in caries prevalence is very different. In these areas an increase in caries prevalence is seen amongst the urban population and those of high socio-economic status, who have access to many Western-style foods. Enwonwu (1974) observed that the caries prevalence amongst educated Nigerians of high socio-economic status, and amongst village children in urban boarding schools, was almost as high as that of Western Europeans living in Nigeria, and the diets of these groups were comparable. In comparison, the low socio-economic status village populations followed a traditional diet low in sugar and high in cereals and starchy foods, and caries prevalence was low. In rural Uganda, Okullo *et al* (2003) noted that sugar consumption amongst highly educated individuals was higher than that of those of lower socio-economic status, but that there was little difference between socio-economic groups in urban areas (both having a high sugar consumption prevalence). Not all clinical studies have observed this trend; no difference in caries prevalence or sugar consumption was found between urban and rural populations in Saudi-Arabia (Al-Shammery, 1999).

Therefore, an association between dental caries and status can exist, but its expression may depend on the cultural definition of 'high status' foods. If these include cariogenic foods, as occurs in developing countries, where a high-sugar Westernised diet is viewed as desirable, then caries prevalence amongst those of high socio-economic status will be high. Conversely, if the desirable foods are not cariogenic, then caries prevalence amongst high-status individuals may be low. A possible example of the latter can be seen in an archaeological Mayan population (c. AD 250-900), where males of high status displayed a caries prevalence that was significantly lower than that of the high status females and low status individuals of either sex (Cucina and Tiesler, 2003). It was suggested that this difference related to a greater consumption of high protein foods amongst the high status individuals, with males having preferential access. Consumption of larger quantities of high protein foods amongst high-socio-economic groups have been noted elsewhere, for example in rural Ecuador, where it was noted that there were no sex difference in diet (Berti and Leonard, 1998). Stable isotope analysis of an Early Medieval British population suggested that individuals of higher status were consuming more herbivore protein than those of lower status, who were eating more fish and omnivore protein; again no sex differences in diet were observed (Privat and O'Connell, 2002). In Late Medieval Britain, it is probable that a situation similar to that in recent developing countries was in existence, with honey, sugar and other expensive foods, such as dried fruits, being available to the wealthy in larger amounts, and perhaps in urban areas to an increased extent (Dyer, 1989, 1998; Drummond and Wilbraham, 1957). It has been suggested that the extremely high caries prevalence recorded in the teeth of eight-year-old Anne Mowbray, a member of the nobility who died in 1481, resulted from her consumption of cariogenic foods that would have been unavailable, or at least available in smaller quantity, to the majority of the population (O'Sullivan, *et al.*, 1993).

4 Medieval Britain

4.1 Introduction.

The Medieval period was chosen for this study due to the availability of numerous collections of skeletal remains, some of which are of considerable size, coupled with archaeological and historical evidence providing information on the diet, environment and living conditions of the time. This combination of biological and cultural data has the potential to enable fuller interpretation. This chapter aims to describe the sources of evidence available and to provide a broad outline of the Medieval period in Britain. The main focus will be on diet, and factors that influence diet, in relation to dental caries.

The Medieval period covers a considerable time-span, over 1,000 years, and can be broadly divided into Early (c. mid-fifth to mid-eleventh centuries) and Late (mid-eleventh to mid-sixteenth centuries) Medieval periods. Overall, this period encompasses numerous episodes of social and cultural change following the collapse of Roman administration in Britain in AD 410, including several influxes of new peoples (Germanic, Scandinavian and Norman) with varying degrees of impact on the existing populations; the emergence of kingdoms; the evolution of social and administrative structures; changes in settlement and farming practices; the development of urbanisation and trading networks; and the growth of the Christian Church. These complex and multifarious changes vary both locally and regionally, and all will have impacted in some form on the health of the populations involved. Whilst recognising this, it would be impossible within the limits of this chapter to discuss these in sufficient detail for all regions concerned, and so an attempt has been made to generalise and simplify the account.

4.2 Background.

4.2.1 Sources of Evidence.

A variety of sources of evidence can be used to reconstruct the events and conditions of the Early and Late Medieval periods, including historical documents and archaeological excavation. Used together, these can be complementary and enrich understanding of the periods involved. Historical sources, both textual and pictorial, tend to focus on politically important people and events, or on the dramatic and unusual, such as terrible storms, famines or plagues (Rackham, 2000). The content of documents is largely determined by the intentions of those who wrote them, those with the ability and the means to do so generally being a privileged group (Cox, 1995; Austin, 1990). Some texts were written long after the events described, whereas others have been copied from earlier manuscripts with possible changes in detail and meaning (Cox, 1995). Other texts are concerned with particular functions, for example the recording of a will or stating the boundaries of a property, and so apply to certain situations and types of people. Although useful, they may contribute little to the detailed understanding of the more mundane, everyday lives of the majority of the population. Documents are fragile, and susceptible to damage and loss; for certain periods or areas they may be few in number, incomplete or non-existent (Austin, 1990; Cox, 1995).

Archaeological excavations provide tangible evidence of the past such as structures, artefacts and the skeletal remains of the people themselves, which have the potential to provide information on the lives of ordinary people. However, this evidence may be biased in that some activities leave more visible traces than others and some types of site, or types of evidence within a site, may be more prone to destruction (Hills, 1999). Location will not only influence preservation but discovery, and so the sites recovered will also reflect modern research activity and industrial/urban development (Ralston and Hunter, 1999; Massagrande, 1995). As a result of financial, topographical or other restrictions, it may not be possible to excavate the entire site, with consequent further loss of data (Ralston and Hunter, 1999). Dating of archaeological sites, and different phases of activity within sites, is usually problematic, as is interpreting the extensive information collected during excavation – a demanding task, which increases in difficulty when dealing with a fragmentary and incomplete record.

The availability of both historical and archaeological evidence varies for different periods and locations. For the Early Medieval period the historical sources are extremely limited, chiefly consisting of the writings of the Venerable Bede (AD 673-735), a Christian monk who lived in Jarrow, Northumbria, and Gildas, a monk who lived in south-western Britain in the sixth century AD (Hills, 1999). A large proportion of archaeological sites of this date consist of cemeteries, and so burial practice and skeletal evidence provides the foundation for most current knowledge about Early Medieval populations (Hills, 1999). The majority of burial and settlement sites identified are located in central, southern and eastern England, as much a reflection of recent developments as past activity: for example many sites in areas of East Anglia and Essex were discovered during gravel extraction (Williamson, 1988). These areas are more likely to favour preservation than the harsher climates and acid soils prevalent in the north and west of Britain, where, to compound matters, the pottery used appears to have been particularly friable and difficult to identify, making recognition of sites problematic (Hills, 1999; Hooke, 1988). Historical and archaeological evidence occurs with greater abundance in the Late Medieval period, but archaeological sites tend to be concentrated in urban areas, reflecting urban regeneration schemes, and problems of interpretation remain.

4.2.2 Historical Framework.

The beginning of the Early Medieval period in Britain is usually dated to around the middle of the fifth century AD, following the disintegration of Roman rule, and it extends to the mid eleventh century AD until the Norman Conquest in AD 1066 (Hills, 1999). Migrating Germanic peoples, the traditional Angles, Saxons and Jutes, arrived in Britain during the fifth and sixth centuries AD and settled in eastern, southern and central England. The nature of the Germanic 'invasion' has been much debated, and it now seems probable that it was on a smaller scale than previously believed and with a greater degree of integration with the indigenous population and evidence of continuity (Reed, 1990; Esmonde Cleary, 1999). The study of stable isotopes is now shedding light on the debate, with its ability to discover the possible childhood origins of individuals (Budd, *et al.*, 2004). Kingdoms had developed by the seventh century AD (Hills, 1999), with an associated re-emergence of towns as administrative and political centres (Dark, 2000). The Anglo-Saxon period in eastern, central and southern England is often divided into 'early' (c. AD 450-650), 'middle' (c. AD 650-800) and 'late' (c. AD 800-1066) (Hills, 1999). Because the indigenous population continued to occupy the western and northern areas (Scotland, Wales, and parts of north and west England) it is inappropriate to apply the label 'Anglo-Saxon period' to these regions (Hills, 1999). For this reason, the term 'Early Medieval' is used in this study to encompass this period in the whole of Britain. However, terminological problems were encountered when dividing this period into sub-periods for data analysis and the term 'Saxon' was used for these, simply to obtain clearer labels for groups of sites; no ethnic connotations are intended with the use of this term.

Deciphering the development of Anglo-Saxon and British cultures is further complicated by the impact of Scandinavian raids, which began in the late eighth century. Danes attacked much of the east coast of England in the decades following the first raid on Lindisfarne in AD 793, and the Norse inflicted raids on the Northern Isles, the north and west of Scotland and north-west England (Hadley, 2000; Richards, 1999; Dark, 2000). The armies began to remain in Britain during the winter in AD 851, and some roamed the countryside for several years (Hadley, 2000). Eventually, in AD 876, the armies began to settle, and parts of the Danish army took up residence in Northumbria, Mercia and East Anglia (the area later to be known as the Danelaw), although raiding continued into the eleventh century (Hadley, 2000; Richards, 1999). The period was characterised by intricate political alliances and military turmoil, described in detail by Hadley (2000), and is much more complex than the view that the English and Scandinavians simply fought each other. As with the Anglo-Saxon influx, the scale and impact of the Scandinavian invasion has been disputed at length (Hadley, 2000; Dark, 2000). Some have argued for mass invasion and settlement, and others for a minor influx of a powerful elite group that exerted its influence over the culture of the population (Richards, 1999). Hadley (2000) concludes that although Scandinavian groups may not have remained distinct from the Anglo-Saxon populations for long, and elements of continuity are present, they did have an important influence on the society of the region.

The date AD 1066 is frequently used as a convenient dividing point between the Early and Late Medieval periods, simply because this is the date of the Norman Conquest. In many ways, 1066 is totally arbitrary, as many of the characteristics of the periods before and after this date remained the same, and it was a while before the impact of the Norman invasion was felt in Wales and Scotland (Hills, 1999). Nevertheless, the Late Medieval period is usually defined as the centuries between the Norman Conquest and the dissolution of the monasteries, which was completed in England and Wales by 1540 (Aston, 2000; Reed, 1990). The appropriation of monasteries in Scotland by the Scottish Crown occurred in 1587 (Reed, 1990). The Late Medieval period, therefore, broadly dates from the mid eleventh century to the mid sixteenth century AD. The Norman invaders primarily consisted of an elite aristocracy, which installed itself at the top of the English social structure.

4.2.3 Burial Practice.

The majority of evidence for the Early Medieval period comes from central, eastern and southern England, and so more is known of the 'Anglo-Saxons' than the indigenous population (Hills, 1999). Cemetery sites in western and northern Britain are scarce, but from those excavated it appears that the existing tradition of unfurnished, west-east burial continued (Lucy, 2000; Hills, 1999). In contrast, a large number of cemetery sites have been excavated in south and east England, where a different funerary rite was practiced. From the fifth to the seventh centuries, the dead were generally buried with grave goods, usually inhumed, but, before the end of the sixth century, cremations in pottery urns are often found in the east (Hills, 1999). The style of burial and grave furnishings resemble those found in continental Europe, although this does not necessarily mean that an individual buried in such a fashion in Britain was of Germanic origin; the indigenous population could have adopted some of the cultural values and practices of the immigrants (Hills, 1999; Lucy, 2000). Burials equipped with grave goods gradually become less common during the seventh and eighth centuries, a change usually attributed to the rising influence of the Christian Church (Lucy, 2000).

From the late seventh century, burial practices gradually began to assume the characteristics of Christianity. Initially, the Church did not insist on burial within consecrated graveyards, although the desirability of burial in a holy place led to large graveyards being formed around Minster churches (Hadley, 2000; Blair, 1988). Increased control over burial rights developed during the tenth century, and by the eleventh century the right to bury corpses was vigorously defended by individual churches (Hadley, 2000; Blair, 1988). Ultimately, "a standard pattern of Christian burial emerged throughout Britain, replacing the older variety of different burial and cemetery types with uniform, unfurnished, east-west oriented inhumations in enclosed cemeteries beside churches in the middle of villages" (Hills, 1999: p188-189). It has regularly been assumed that Scandinavian burials will be obvious, being pagan burials furnished with grave goods at a time when the Anglo-Saxon population was largely adopting Christian burial practices. However, few such burials have been identified, the majority occurring as single burials within Christian cemeteries. It is difficult to distinguish whether these are 'Scandinavian' or 'Anglo-Saxon', and Hadley (2000: p29) has warned that it is "dangerous to assume religious belief or ethnic affiliation on the basis of grave goods". Again, the study of stable isotopes may help resolve the issue (Budd, *et al.*, 2004).

The Late Medieval period is dominated by Christian burial practices, with the majority of the population being buried at their parish church. This has resulted in well-demarcated graveyards, with all individuals, in theory, subjected to the same burial rite, although status came to be expressed through burial location. Being buried as close as possible to the church was desirable, and burial within the church even more so – the closer to the high altar or the tombs of saints the better (Daniell, 1997; Horrox, 1999). The opportunity for the latter was largely restricted to the clergy, and wealthy individuals who could afford it. An alternative was burial within a religious house, again a distinction primarily reserved for monks, friars, canons, nuns, and wealthy benefactors (Horrox, 1999; Daniell, 1997). The rights to bury individuals, and thus secure the fees, were fiercely negotiated between religious institutions and parish churches.

4.3 Diet, Social Status and Religion.

Food provides the body with the energy and substrates necessary for growth and development; it is also an important factor in dental health. The types of foods eaten will have an effect on the teeth and soft tissues of the mouth, and variations in diet have a strong influence on the development of dental caries (see Chapter 3). Diet is obviously restricted to the foods available, whether self-produced or bought, and therefore dependent on subsistence practices and economy and influenced by season – the types of plant foods grown and animal foods produced, the amount of surplus for sale, the presence of trading networks and adequate transport are all important. However, access to foods may be determined by social status. Some foods may be expensive, and so affordable only by the wealthiest individuals; in contrast, the poorest groups may lack the resources to supply themselves with the most basic adequate diet (Dyer, 1998, 1989). The poor would also have been more vulnerable to seasonal shortages and the risk of famine, having fewer resources and being more dependent on a narrow range of basic foods (Dyer, 1989). Cultural values become attached to food, with the result that the upper class disdain foods that they perceive to be indicative of poverty, whilst those of lower status aspire to the diets of their social superiors (Visser, 1991; Dyer, 1998). Cultural practices, for example the strict dietary regulations imposed by various religious Rules, may also affect the foods available to certain people: what is eaten, when, and by whom. There may also be differences in the foods eaten by males and females, or adults and children, which are culturally defined (Visser, 1991; Messer, 1989). Conversely, just because such customs (whether explicit or implicit) exist, does not mean they are always observed.

The following sections will discuss the diets of Early and Late Medieval British populations, including differences in diet related to social class or group. Evidence for diet comes from plant and animal remains recovered from archaeological excavations, and documentary sources. The latter, as always, are much more common and informative for the Late Medieval period. The former, although a direct source of information, are subject to problems of interpretation. The usual issues arise concerning the preservation and recovery of what, in many cases, are small and fragile remains (Dark, 2000; Wing, 2000). Not all the animal remains recovered from archaeological sites will be from animals consumed (Wing, 2000). Large animals may be over-represented, as their bones are larger and more obvious; conversely, although the remains of small animals may be more numerous, being small their contribution to the diet may be less important than that of the larger animals (Wing, 2000; Brothwell and Brothwell, 1998). Fish bones, in particular, may be difficult to recover and, unless a diagnostic portion of the skeleton is recovered, virtually impossible to identify to species (O'Connor, 1991; Wing, 2000). Similar problems occur with plant remains, many of which are only preserved in waterlogged soils such as peat bogs. Many of these samples will not be obtained from an archaeological site, or even from regions in the vicinity of an archaeological site, and so there may be problems relating the evidence to the archaeology (Dark, 2000). Pollen records will over-represent wind-pollinated plants that produce copious quantities of pollen and under-represent those relying on insects for pollination. It is impossible to identify the species of some plants from their pollen, and this includes cereals and grasses. In addition, it is difficult to determine the catchment area of the sample, or whether the pollen derives from wild or cultivated plants (Dark, 2000). Macroscopic plant remains, such as charred grains, can provide direct evidence on the plants grown and consumed, although some plants may have been weeds or grown for other purposes (Dark, 2000).

4.4 Early Medieval Diet.

4.4.1 Sources of Food.

The Early Medieval period was dominated by rural settlement and agriculture, and experienced a favourable climate (Hills, 1999; Fowler, 2002; Hall, 1988; Hinton, 1990; Bell and Walker, 1992). It is reasonable to assume that most of the food consumed by the majority of the population would have been locally produced through mixed arable and livestock farming (Reed, 1990). Archaeological evidence suggests that cereals were grown in all areas of Britain, including the highland zones of the north and west. Bread wheat (which had largely replaced the more traditional emmer and spelt wheats by the fourth century), rye, barley and oats were the staple cereals produced in England, supplemented by legume crops of peas and beans (Fowler, 2002; Dark, 2000; Hinton, 1990); little evidence exists for Wales and Scotland, although it is likely that barley and oats were grown (Fowler, 2002). However, regional variation existed. Rye was more commonly cultivated in the sandy soils of eastern England (Dark, 2000), whereas the less favourable climate and altitude of upland areas would have necessitated dependence on oats and barley (Fowler, 2002). Domestic livestock, throughout the period, predominantly consisted of cattle, sheep and pigs (Fowler, 2002), with the addition of goats, fowl, and a small number of horses (Dark, 2000; Fowler, 2002). These animals would have been smaller than those of today, and some may have been kept for secondary products, such as milk, eggs, wool, traction and transport, as well as for meat (Fowler, 2002).

Additional sources of food would have been grown in gardens, or collected from the wild. Vegetables, mainly cabbages, lettuce, onions, leeks, and garlic, but also turnip, carrots, parsnip, beet and cucumbers, were grown in gardens along with herbs, which had value as medicine as well as food (Hagen, 1992; Cameron, 1993; Fowler, 2002). Apples were the most common tree fruit, but plums, damsons, cherries, quince and nuts were also available. Berries frequently included sloes, juniper, rowan berries, elderberries, strawberries, raspberries and blackberries (Hagen, 1992; Cameron, 1993;

Fowler, 2002). It is likely that fungi were also collected (Fowler, 2002). Bees were kept for their honey, but honey may also have been 'hunted' in the wild (Hagen, 1992; Fowler, 2002; Brothwell and Brothwell, 1998). Occasionally the remains of wild animals are found on archaeological sites, including red and roe deer, hare, boar, and birds (e.g. goose, duck, woodcock, pigeon, blackbird, finches, rook, crow and jackdaw) (Fowler, 2002; Dark, 2000). The rights to hunt many of these may have been reserved for the upper classes, as in the Late Medieval period, although the less well off may have found the opportunity to hunt covertly the smaller wild birds (Cameron, 1993; Fowler, 2002). Fish and other marine and freshwater resources were also exploited: "Fish were eaten fresh, dried, smoked and salted, from marine and riverine habitats, local and imported" (Fowler, 2002: p241). Species include: eels, salmon, roach, burbots, lampreys, pike, trout, sturgeon, minnows, herring, plaice, and flounder (Fowler, 2002; Cameron, 1993).

4.4.2 Peasant Diet.

The staple diet of the peasant population would have been heavily cereal-based. Bread was usually leavened, and the poor would probably have eaten coarse rye or maslin (a mix of rye and wheat) bread rather than the more expensive wheat bread eaten by the upper classes (Cameron, 1993; Hagen, 1992). In upland areas, bread would have been made from oats (Drummond and Wilbraham, 1957). Grains would also have provided the basis for pottages, and barley was used to brew ale, commonly drunk instead of water (Cameron, 1993; Hagen, 1992, 1995). This basic diet of bread, pottage and ale would have been supplemented with peas and beans, and limited fruit, vegetables and herbs (Fowler, 2002; Cameron, 1993; Hagen, 1992). Some degree of dairy produce would have been available to the poor: milk from cattle, sheep and goats, cheese, butter (used mainly for cooking), and eggs (Cameron, 1993; Hagen, 1992). Meat consumption amongst the peasant class would have been minimal, although fish may have been more commonly available (Fowler, 2002). A study of stable isotope ratios in the skeletal remains from Berinsfield, Oxfordshire, has suggested that freshwater fish formed a more important part of the diet of poorer individuals, whereas the wealthier consumed more herbivore protein (Privat and O'Connell, 2002). Inland, fish would have been caught in rivers and lakes, but in coastal areas some exploitation of marine foods and inshore fish is likely to have occurred (Hagen, 1995). Cameron (1993) surmises that the diet of the majority of the population would have been inadequate, as sufficient quantities of necessary foods would have been unavailable, particularly in winter or following poor harvests. Sub-clinical dietary deficiencies may well have been common, especially a lack of vitamin C from the small quantities of vegetables, herbs and fruit, and iron deficiency from the low meat consumption (Cameron, 1993; Fowler, 2002). The latter may have been particularly serious for adult females (Cameron, 1993), and Hagen (1992) has suggested that women and children may have been more likely to suffer from undernutrition if adult males had preferential access to food in times of shortage.

This diet is unlikely to promote the development of dental caries. Even though large quantities of carbohydrates were consumed, the majority were unrefined and so less cariogenic, although the boiling of grains in pottages may have produced food of a soft and sticky texture, which could have exerted some cariogenic action (see Section 3.3.2.1). Honey was the main sweetening agent, and it was used frequently in Anglo-Saxon medicines (Cameron, 1993). Since honey contains high proportions of non-milk extrinsic sugars, including sucrose, it is likely to be more cariogenic than most other foods available at the time. It is unclear to what extent honey was available to the poorer classes, although it seems reasonable to assume that, like many other items, large quantities were not consumed. The only other sugars present in the diet were the less-dangerous intrinsic sugars from fruits and berries (fructose) and vegetables (glucose), which were consumed in small quantities, and lactose from milk (Moore and Corbett, 1971), which is less cariogenic than the other sugars. The consumption of marine fish and other seafood may have provided an additional protection against the development of caries due to their raised fluoride levels, but this was a resource only available to those on the coast. In addition, the coarse texture of the food encouraged dental attrition, which, through obliterating the pits and grooves in the molars, may have reduced the prevalence of caries in the tooth crown; it could also have removed enamel and dentine with developing carious lesions, preventing them from progressing (Silverstone, 1990). Coarse-textured food is also less likely to adhere to teeth and collect in small pits and fissures, and would have cleansed the teeth. However, Freeth (1999) has argued that coarse foods are more likely to exert an effect through increased stimulation of saliva than through any self-cleansing mechanism or through the action of heavy attrition.

4.4.3 Upper Class Diet

Freeth (1999) has suggested that diet in the Early Medieval period was largely egalitarian, as with little trade in exotic and luxury foods there would be less opportunity to display status through diet. Whilst Privat and O'Connell (2002) observed that all individuals examined at Berinsfield, Oxfordshire, had access to animal protein, they found that the wealthier individuals displayed stable isotope ratios consistent with consumption of more herbivore protein, whilst the poorer individuals appeared to have consumed more freshwater fish and omnivore protein. Therefore some differences in diet may have existed although the differences are not likely to have been marked. Like the peasant diet, upper class diet would also have been based on the staples of bread, ale and legumes, accompanied by fruit, vegetables and dairy produce. However, their bread would have been fine, white wheaten bread and they would have been able to include a larger quantity and variety of meat and fish in their diet (Cameron, 1993). The presence of more refined carbohydrates is a factor that could have increased cariogenicity, but the inclusion of more protein would not have been detrimental to the health of the teeth. In addition, they could probably afford and obtain imported spices, dried fruits and wine. Mead, fermented from honey, was also an expensive drink that was likely enjoyed by the upper classes (Brothwell and Brothwell, 1998). Less affected by seasonal availability or shortages due to crop failures, their meals were generally substantial and luxurious (Fowler, 2002). Certain aspects of their diet, such as the use of finer flour, may have placed them at greater risk of dental caries than the peasant population. It is probable that honey was more widely used in food preparation, and in addition there were the concentrated non-milk extrinsic sugars contained in the sticky dried fruits, which are known to be cariogenic (Nelson, *et al.*, 1999). However, on balance the diet was still remarkably free from cariogenic agents.

4.5 Late Medieval Diet.

The feudal system of the Late Medieval period continued the mixed arable and livestock farming of the preceding centuries. Crops were grown in large open fields, which were divided into strips distributed amongst the peasants, who farmed the fields in rotation. Animals were grazed on common land or wasteland, and also on the stubble of the open fields following the harvest (Drummond and Wilbraham, 1957;

Dyer, 1989; Rackham, 2000). The peasants were under varying degrees of obligation to the lord of the manor. Free tenants simply paid a low rent and were much better off than the unfree tenants, whose rents were higher and who also had to provide a certain amount of labour on the manorial land in addition to farming their own (Dyer, 1989; Drummond and Wilbraham, 1957). The balance changed in the latter half of the fourteenth century, following the devastation of the Black Death. The shortage of labour eventually meant that many peasants were able to bargain for better working and living conditions, and most were able to buy their freedom from the tenurial system, which disintegrated by the mid fifteenth century (Dyer, 1989; Drummond and Wilbraham, 1957). Again, the rural population was dependant on the food they produced, and the lords and gentry were dependant on the labour and taxes of the peasants. However, a market economy was developing, especially since surplus produce would have been required to sustain the expanding urban populations (Carlin, 1998). The towns themselves provided a focus for trade, and the opportunity to purchase imported foodstuffs.

As before, the cereal crops grown consisted of wheat, barley, rye and oats, and again regional differences existed (Drummond and Wilbraham, 1957). In the south, particularly in Essex and Surrey, a high proportion of wheat was grown, although wheat was replaced by rye in some counties, for example Norfolk (Dyer, 1989). Wheat and rye were found in the northeast, and oats in the northwest (Dyer, 1989). In Scotland, and presumably other upland areas, oats were the principal cereal crop, supplemented with barley (Reed, 1990). Peas and beans would also have been grown (Drummond and Wilbraham, 1957). Gardens would have continued to produce herbs, vegetables and fruit. The main vegetables would have been onions, garlic and leeks, with cabbages, radishes, spinach and lettuce and occasionally parsnips, turnips, carrots and beets (Drummond and Wilbraham, 1957; Dyer, 1989). Fruit would have included apples, plums, cherries and pears (Drummond and Wilbraham, 1957; Dyer, 1989). It is likely that the range of berries and fruit would have included those available in the preceding period. The principal domestic livestock were again cattle, oxen, sheep, pigs and poultry (Drummond and Wilbraham, 1957), with a few horses (Dyer, 1989). Wild animals and birds would have been exploited where possible. A substantial number of fish would have been caught or farmed, and with the development of the fishing industry marine fish were traded far inland (Dyer, 1988, 1989; Bond, 1988;

Steane and Foreman, 1988). Imports of spices (including sugar), dried fruits (raisins, currants, dates, prunes, figs), almonds, rice, wine and oil increased throughout the period, although they would have been affordable only by the wealthy (Dyer, 1989).

4.5.1 Peasant Diet.

Most documentary sources of evidence, such as estate accounts, recipe books, and descriptions of feasts, provide information on the diet of the upper classes; it is much harder to gain information on the diet of the poor (Dyer, 1998). Dyer (1998) has attempted to reconstruct the likely diet of the peasant population for the period AD 1290-1500. Much as in the Early Medieval period, the peasants subsisted on a basic, cereal-based diet of bread, pottage and ale (Dyer, 1998; Drummond and Wilbraham, 1957). The type of cereal used to make bread depended on the cereal grown in that region: wheat-bread in Essex and Surrey, barley- or rye-bread in Norfolk and Worcestershire (Dyer, 1998). Barley would have been used to make ale, although since a hefty portion of the grain calories are lost during brewing it would not have been drunk regularly by the poorer peasants (Galloway, 1998), and was also combined with peas as the basis of a pottage (Dyer, 1998). Oats featured heavily in the diet of the populations of Devon, Cornwall and the north of England, with oats used in pottages and used to brew ale, and also to make oat cakes (Dyer, 1998). Peasants are believed to have kept small gardens and had access to orchards, and therefore their diet would have included some vegetables and fruit. Some peasants would have owned animals such as pigs (providing bacon), poultry (eggs and meat), sheep and cattle (a source of milk, cream, cheese, and butter as well as meat and wool) (Dyer, 1998; Drummond and Wilbraham, 1957). Fish would also have been affordable, especially salted herring and dried cod, and for those living in coastal areas or fenland, widely available (Dyer, 1998). Mays (1997) has reported evidence from stable isotope values that remote inland populations were eating marine fish in the Late Medieval period. However, the quantities of meat, fish and dairy produce in the diet would have been relatively small in comparison to the amount consumed by the wealthy (Dyer, 1998).

The economic circumstances of the individual peasant would have dictated the quality and quantity of different foods in their diet. The amount of land held would have been crucial in determining whether a family was able to be self-sufficient, producing enough both to feed themselves a reasonably balanced diet and generate an income for the purchase of additional items (Dyer, 1998). Another important factor was the nature of their tenancy, as unfree farmers were required to spend a portion of their time labouring on the lord's land and also had higher rents to pay, leaving less time for farming their own lands and absorbing a considerable amount of their income. Labourers holding no land were obliged to buy all their food. Family size and composition would have also had an impact on their circumstances; children require feeding, but those old enough were capable of working and contributing to the family income (Dyer, 1989).

The prevailing social and economic structure also influenced the peasant diet. In the first half of the Late Medieval period, the peasant population was numerous, lords demanded ever-higher rents and fines from their tenants, and work was in short supply and poorly paid (Dyer, 1998). Under these conditions, the diet of the peasant population was minimal. Based on evidence for the diet of harvest workers, which would probably have been better than their usual diet (Swabey, 1998), Dyer (1989) has calculated that approximately three-quarters of the dietary calories were derived from cereals in the form of barley bread and oatmeal pottage. These were accompanied by small quantities of herrings, salt cod, cheese and bacon. The successive years of poor harvests in the early part of the fourteenth century had a devastating effect on the peasant population, particularly those scraping a marginal existence as labourers or smallholders (Dyer, 1998, 1989). From the late fourteenth century, following the Black Death and subsequent economic changes, the peasant situation improved markedly. With increased size of landholdings, lower rents, higher wages and demand for labour came the ability to purchase more and better food (Galloway, 1998; Drummond and Wilbraham, 1957). The diet supplied to harvest workers (again, not representative of the normal diet) shows the replacement of barley-bread with wheat-bread, bacon with larger quantities of fresh meat, dried and salted herring and cod with fresh fish (Dyer, 1998). Attempts by the peasantry to emulate their lords led to the consumption of larger quantities of meat and fish, ale and white wheaten bread at the expense of fruit and vegetables (Dyer, 1998).

In general, the peasant population would have existed on a barely adequate diet, experiencing periods of seasonal deprivation and exposed to the risk of famine if the harvest failed. As in the Early Medieval period, many individuals must have experienced nutritional deficiencies, such as vitamin C and iron. The likelihood of vitamin C deficiency probably increased from the late fourteenth century as less fruit and vegetables were consumed. The risk of caries would again appear to be low. Large amounts of unrefined carbohydrates were consumed and these would not have been particularly cariogenic, although the tendency towards eating bread made from more finely ground and whitened flour later in the period might have increased the risk. Sugar would have been present in fruits, milk and honey, but the intrinsic sugar in fruit and the extrinsic sugars (lactose) in milk would not have been that cariogenic. The sugar present in honey is more dangerous, but again the quantities consumed by the poor must be questioned. The importance of dairy produce in the diet of the poor would have helped protect against dental caries, and the marine fish consumed might also have exerted a beneficial effect.

4.5.2 Upper Class Diet.

A conspicuous difference between the diet of the upper class and that of the peasants was the sheer quantity, as well as variety, of food consumed by the former. With ample resources they could afford a plentiful supply of food, and the meals served and dishes consumed were more elaborate (Labarge, 2003; Drummond and Wilbraham, 1957). Although the upper class also relied on cereal staples, in the form of bread and ale, white, wheaten bread was favoured over the cheap, coarse rye- or barley-bread consumed by the peasants, and imported wine was drunk as well as ale (Labarge, 2003; Dyer, 1989). One of the major differences, though, was the considerable amount of fresh and preserved meat and fish consumed. Each year, between AD 1350 and 1530, an average of £118 (19.2% of the total income) was spent on meat, £45 (7.4%) on poultry and £92 (14.9%) on fish by households greater than 50 people, and an average of £87 (20.3%) was spent on meat, £34 (7.9%) on poultry and £92 (21.4%) on fish by smaller households (Mertes, 1988). The meat included beef, mutton, pork, veal, poultry, and game birds and animals of various kinds; venison was a particularly high status meat (Dyer, 1989; Labarge, 2003). Fresh fish were obtained, via trade, from the sea, and from managed stew-ponds on the lord's estate; varieties included herring, cod, ling, winterfish, haberdens, salmon, eels, pike, bream, perch, carp, barbell, roach, dace, mackerel, mullet, flounder, plaice, sole and minnows (Dyer, 1989; Nash, 2000; Labarge, 2003). The quantities of fish consumed by the medieval household could be substantial: for example, between 400-1,000 herring were consumed each day during Lent by the household of the Countess of Leicester (Labarge, 2003).

Dairy produce was also consumed, as were fruit and vegetables, although they were generally not considered to be important or high status foods, and so quantities may have been more limited. However, fruit and vegetables would have been grown in the orchards and gardens of the household, and cheese in many cases was probably self-produced, and so these items would not figure prominently among the purchases recorded in the household books of the time (Mertes, 1988; Labarge, 2003). Imported foodstuffs were also a feature of the upper class diet. Many of the meat and fish dishes were flavoured with spices, although the quantity and frequency with which they were used would have depended on wealth (Dyer, 1989; Labarge, 2003). Dried fruits, such as raisins, currants, dates, prunes and figs, were imported from Portugal and the Levant and were widely used ingredients (Drummond and Wilbraham, 1957); for example 20,800 pounds of currants were purchased in one year by the household of the Fifth Earl of Northumberland (Mertes, 1988). Honey continued to be used as a sweetener, and as a means of preserving fruits and vegetables, although imported sugar became cheaper, more available and more frequently used (Hammond, 1993; Brothwell and Brothwell, 1998; Black, 1992; McKendry, 1973).

Sugar was extracted from the sugar cane plant in India by the middle of the first millennium BC, and by the seventh century AD it had reached the Mediterranean (Galloway, 2000; Brothwell and Brothwell, 1998). Bede is reported to have left sugar, amongst other spices, to the brethren on his death in AD 735, but the next mention of sugar does not occur until the twelfth century, when a reference to it appears as a condiment in the court of Henry II (Hagen, 1995; Hammond, 1993). Although Hobhouse (1999) states that sugar was not imported into England until AD 1319, "a close study of [household] accounts shows that sugar was in continuous use in wealthy households by the middle of the thirteenth century" (Labarge, 2003: p95-96). At first it was an expensive commodity, and the small quantities available did not form a regular part of the diet, although it was probably used in medicines (Hobhouse, 1999; Brothwell and Brothwell, 1998); Labarge (2003) observes that sugar and sugar syrup were used in the treatment of Henry, the sick young son of Edward I. The price of sugar dropped considerably between 1350 and 1550 (Hobhouse, 1999), making it more affordable for a larger portion of the population, and larger quantities affordable for the wealthy. At all times wealth would have determined the amount of sugar bought, as suggested by the household books of John Howard, Duke of Norfolk: in the mid 1460s he was a wealthy, but untitled, landowner and the quantities of sugar bought are small, with infrequent purchases of a pound (or less) of sugar at a time; by the early 1480s he had become an incredibly wealthy baron, and the amount of sugar bought increased, with many more purchases of several pounds of sugar (on one occasion 20lb) between 1481 and 1483 (Crawford, 1992). Recipe books from the fourteenth and fifteenth centuries include many recipes with sugar as an ingredient. Of the 96 recipes listed in McKendry (1973) 34 require sugar, and of the 42 recipes in Black (1992) 20 mention sugar. Most quantities involved are small, being a pinch or the equivalent of less than a teaspoon, although some of the recipes call for larger amounts. The recipes with sugar included many main savoury dishes as well as dessert dishes. The recipes in these books are likely to have been those served at special occasions, such as feasts. These were extravagant affairs, with multiple courses of meat and fish, each consisting of several dishes, and each concluded with a sweet pastry, sweetmeat or 'subtlety' (an elaborate sculpture of sugar and paste) (Black, 1992; McKendry, 1973; Labarge, 2003). One of the functions of a feast is to display the wealth and status of the host, and so luxurious and expensive foods were served (Mertes, 1988). Again, an example can be found in the household books of John Howard, where a list of the food bought for a feast given when he was knighted (April 1467) includes 5s spent on "powdre of synamon, gynger and suger", 4s spent on "safron, hony and sawndres", and 18d spent on "reysans of corauns" (Crawford, 1992: p I 399). This food would not be representative of the daily upper-class diet. The early fifteenth century household accounts of Alice de Bryene have been used to reconstruct the meals served at a rural manor during the course of a year, and the consumption of sugar was noted to be low (Swabey, 1998).

The influence of the Church on diet was considerable. Three days of the week were declared to be 'fast days' (Wednesdays, Fridays and Saturdays), when meat was forbidden and replaced with fish, although consumption of meat was permitted for the sick and licences could be bought to allow an individual to eat flesh on a fish day (Dyer, 1989; Drummond and Wilbraham, 1957; Hagen, 1992; Mertes, 1988). During the six weeks of Lent the prohibition extended to dairy produce as well as meat (Dyer, 1989). These regulations would have had more of an impact on the wealthy, as "the observance of such a fast was only relevant to those who normally expected to enjoy plenty, and abstinence was almost as much an aristocratic indulgence as feasting" (Dyer, 1989: p66). In contrast, the peasants would have "observed Lent out of necessity as well as piety" (Dyer, 1998: p60), spring and early summer being a time when reserves of stored food were low and the new crops were not ready for harvest. They would have viewed "the supposed rigours of aristocratic Lent as the height of luxury" (Dyer, 1989: p66).

The diet of the upper classes, although more plentiful, was not necessarily healthier than that of the peasant class, and elements of the diet would have certainly promoted the development of dental caries. Sugar, although not consumed in large quantities on a regular basis, was becoming an established part of the diet and it is likely that the amount and frequency of consumption increased with the wealth of the individual. Towards the end of the period, sugar would have been available to an ever-increasing section of the population. In addition, honey was widely used as a sweetener, as a preservative and in medicines, and dried fruits were ingredients in many dishes and were frequently enjoyed. With many more sources of non-milk extrinsic sugars in their diet, the gentry and nobility were probably placed at an increased risk of developing dental caries compared to the peasant population. The preference for white bread made from finely ground flour, and combinations of carbohydrate foods with foods containing sugars, could have also contributed to the risk of caries. However, the quantities of meat and fish consumed would not have placed teeth at risk, and the consumption of large quantities of marine fish would likely have been beneficial in protecting against the development of caries.

4.5.3 Urban Diet.

Towns increased in size and number during the twelfth and thirteenth centuries in response to growth in prosperity and trade (Dyer, 1989; Talbot, 1967). Sustaining the urban populations required the provision of food from the surrounding countryside, as well as imports from further afield (Murphy, 1998; Carlin, 1998). There was a large variety of food available in the markets, including grain, meat, fish, dairy produce, fruit, vegetables, and all manner of imported goods, but the cost was high. The exception was the opportunity provided by towns to buy luxuries in bulk, thus making them cheaper than in the countryside (Dyer, 1989; Labarge, 2003; Mertes, 1988), and there are examples detailing the costs of, and arrangements made for, transporting goods purchased in towns to the rural estate in the household books of John Howard (Crawford, 1992). Wealthy individuals would have supplied their urban residences in part with the produce from their rural estates, as well as growing food in their town house gardens and buying in quantity from the markets (Dyer, 1989). Much of their food would have been prepared in their kitchens from raw ingredients (Carlin, 1998). The bulk of the population would have relied on food purchased at markets, and since many lacked cooking facilities much was available ready-cooked, for example bread, and joints of meat or meat pies sold by cookshops (Carlin, 1998). In general, the patterns of diet already described for the upper and lower classes would have remained the same in towns. It is probable that exotic foods were cheaper and easier to obtain in urban centres, which may have increased the consumption of sugar for the upper classes, although they would have been in a position to transport such goods to their rural estates.

4.6 Monastic Diet.

Several Celtic monasteries were established in remote locations in the north and west of Britain as a result of the influence of monks from Ireland around the late fifth century (Aston, 2000; Reed, 1990). These early monks lived an ascetic and eremitical existence, following a Rule that was a version of that of St. Benedict combined with local customs (Cramp, 1999). Dietary regulations of Benedictine Rule were strict, forbidding the consumption of meat (unless sick) and recommending frugal meals limited to a choice of two dishes, with a third of fruit and vegetables if these were available, accompanied by bread and ale; this main meal was supplemented by a supper of bread and ale in the summer, but not in winter (Parry and de Waal, 1990; Fry, 1981). Although the local customs introduced by the individual abbots will have varied it seems likely that the monastic diet in this period consisted of coarse bread, pottage and ale, with fish eaten instead of meat, dairy produce (cheese, milk and eggs) and some fruit and vegetables; honey may also have been available (Hagen, 1992). Few aspects of this diet are cariogenic. The unrefined carbohydrates and lack of sugars would not provide much substrate for metabolisation by oral bacteria, although the degree of processing before and during cooking will affect the consistency of the food and alter its cariogenicity, and the non-milk extrinsic sugars of honey will have been a risk if consumed often or combined with sticky carbohydrates. The presence of cheese would promote remineralisation of teeth. Many monasteries appear to have been coastal, or located on remote islands, and so marine fish will have been an important part of the diet, another factor that will benefit the teeth. The infrequent consumption of food would also have been a protective factor against dental caries.

In AD 597, the mission of the Roman Church arrived in Kent and by the seventh century monasteries were established across England and most of Britain had been converted to Christianity; by the eighth century the influence of the Celtic church had been replaced (Aston, 2000). Many monasteries in the east of Britain suffered considerably during the Viking raids of the ninth century, and regular organisation broke down. Following the drafting of the *Regularis Concordia* in AD 973 the Rule of St. Benedict was established as the only Rule to be followed, and many new monasteries were founded during the tenth and eleventh centuries (Aston, 2000; Burton, 1994). After the Norman Conquest the existing Benedictine monasteries were reformed and many new ones founded (Reed, 1990). Dissatisfaction with religious life in existing monasteries led to the founding of new religious orders, each with different ideals and rules. The Cistercian order, founded in AD 1098, strove to re-establish the stringent Rule of St. Benedict, now largely abandoned by the Benedictine monks (Aston, 2000; Burton, 1994; Brooke, 2003). In the twelfth century the Augustinian Canons adopted a more relaxed rule, allowing greater freedoms and a more amenable daily routine (Burton, 1994; Aston, 2000; Brooke, 2003; La Corte and McMillan, 2004). Beyond recommending fasting and abstinence, there are no specific details regarding diet, and it seems that the Rule could be adapted to suit the requirements of each institution. Various orders of mendicant friars arrived and established themselves in Britain during the early thirteenth century (Burton, 1994; Aston, 2000). The popular orders of Dominicans (Blackfriars) and Franciscans (Greyfriars) were forbidden property or possessions and subsisted on begging and alms. They believed in actively preaching to, and serving, the poor community and so were located in towns (Reed, 1990). The Franciscans followed the Rule of St. Francis, but the Dominicans followed an adapted version of the Augustinian Rule, with stricter details on food and fasts (La Corte and McMillan, 2004). The Dominican constitution was also adopted by the Carmelite Friars (Whitefriars) and Augustinian (Austin) Friars. Despite the intention to live in extreme poverty, this ideal was gradually conceded (Burton, 1994).

Within all orders it was the case that "sometimes the Rules were followed to the letter, but at other times they were nearly ignored. Reform after reform brought members of the orders back to their Rules; periods of laxity and reform occurred in cycles (La Corte and McMillan, 2004: p12). More has been written on the Benedictine monasteries and their changes in diet than on the other religious orders. From the late twelfth century onwards it seems as though ever more complex arguments were constructed to define exceptions and justify deviations from the Rule, with the result that there was a gradual relaxation of principles and the majority of the most austere ordinances were evaded. The definition of 'meat' came to exclude pre-cooked meat, or the entrails and offal of quadrupeds, and dishes containing these were termed 'meaty dishes', and it had long been argued that poultry were not meat (Harvey, B., 1993; Knowles, 1962). It was also reasoned that, since the Rule specifically referred to meals consumed in the Refectory, any food consumed elsewhere was not subject to the same stringent regulations. Accordingly, a second room, the Misericord, was built for the consumption of irregular meals (Knowles, 1962). The situation was admitted officially in 1336, when the Pope ordered that at least half the total number of monks in the community must eat in the Refectory, and that irregular food must not be consumed anywhere on fast days, i.e. Wednesdays, Fridays and Saturdays, or during Lent and Advent (Harvey, B., 1993). However, the definition of 'total monks in the community' gradually came to exclude the sick, those absent from the monastery, or those invited to eat with the abbot (Harvey, B., 1993). Therefore, on fast days, all monks ate fish in the Refectory, and on flesh days, half the monks ate meaty dishes in the Refectory and the other half ate meat in the Misericord (Harvey, B., 1993). At Westminster Abbey a third room was created to allow all monks to eat supper during winter – none were allowed to eat supper in the Refectory, but only half were allowed to eat in the Misericord. The resulting arrangement is neatly described by Harvey B. (1993: p42): "Moving adroitly between these rooms, but remembering, when appropriate, that all must not move at once, the Late Medieval community managed to have supper as well as dinner on five or six days a week throughout the year, outside the fast seasons of Advent and Lent, and to eat meat on four days a week - Sundays, Mondays, Tuesdays and Thursdays - outside these seasons".

By the Late Medieval period the monastic diet was in many ways equivalent to the upper class diet described above, and so potentially considerably more cariogenic than that of the Early Medieval period. The excessive numbers of dishes provided at meals prompted efforts to regulate the number of dishes per person, according to status (Drummond and Wilbraham, 1957). Dinner consisted of several main dishes of meat or fish according to day and location, with additional speciality dishes (pittances), accompanied by bread, cheese and ale, or occasionally wine (Harvey, B., 1993). At supper, cheese and a couple of cooked dishes were added to the bread and ale (Harvey, B., 1993). An ample supply of honey was available with which to sweeten dishes, and dried fruits were frequently eaten during Lent and included in bread (Black, 1992). It is likely that some sugar was also included in the diet. The presence of honey, sugar, and dried fruits in the diet in any quantity would have been detrimental to the teeth, especially if combined with processed and refined carbohydrates. Bread was often made from wheat flour, compared to the coarser bread originally consumed, and it is likely that fruit and vegetables decreased in importance in the diet. Except for the period of Lent, dairy produce appears to have been a significant part of the diet (Harvey, B., 1993), and this predilection for cheese, particularly at the end of a meal, would have afforded some degree of protection from caries. The considerable consumption of marine fish developed in the later Medieval period, despite the acceptance of, and increase in, meat consumption: Harvey B. (1993) has calculated that a monk in Westminster Abbey ate fish on roughly 215 days a year, half of which was preserved, and that almost all the fresh fish consumed came from the sea. Mays (1997) has demonstrated a high marine food consumption in the monastic population at St. Andrew Fishergate, York in comparison to the lay population, and careful excavation at a monastery in Belgium has also demonstrated the importance of marine fish in the diet (van Neer and Ervynck, 1996). Therefore, it is likely that high fluoride levels were a part of monastic diet. On balance, it appears that a monastic diet of the Late Medieval period was similar to that of the upper classes in many ways, but that a higher marine fish and cheese consumption may have placed the religious inhabitants at less risk of caries development. It also seems likely that they would not have consumed as much dried fruits, sugared foods or honey. However, their diet certainly seems likely to have been more cariogenic than that of the general population and also than that of early monastic communities.

4.7 Summary.

The diet of the majority of the population during the Early Medieval period was dependant on locally produced resources, and although some differences in diet likely existed between groups of different status these may not have been substantial. Cereals were the staple of the diet for both upper and lower classes, although the carbohydrates consumed by the upper classes may have been more refined and therefore more cariogenic. Vegetables and fruit were a part of the diet, but probably would not have placed teeth at risk. Meat and fish were consumed by all, although more of both would have been consumed by the wealthier elements and fish probably formed a higher proportion of the lower class diet compared to meat; marine fish would only have been available to those near the sea and the quantity and variety of marine fish were not as great as were caught during the Late Medieval period. Cheese and milk probably formed a larger proportion of the lower class than the upper class diet. Honey was the main sweetening agent, and more was likely to be available to the wealthier individuals. Monastic communities were adhering to a strict Rule, with a diet based on coarse bread, pottage and ale, eschewing meat in favour of fish, and consuming some fruits and vegetables. This diet may have been even less cariogenic than that of the general population.

In the Late Medieval period the expansion of trade and development of towns provided increased opportunity for diversification of diet for the wealthy, but the poor would still have been largely restricted to what was locally produced. Their diet appears to have changed little from that of the earlier periods, although a trend towards using more refined flours for bread would have increased the cariogenic potential of the diet slightly. The wealthy could afford more expensive delicacies and cariogenic foods such as dried fruits, imported sugar, and honey, but still the quantities of sugar would have been low in comparison to modern standards. The diet of the wealthy is therefore likely to have increased in cariogenic potential more than that of the general population, but the cariogenicity of the diet was still not as great as that of more recent times. The diet of the monastic communities is also likely to have changed considerably from the earlier period if, as seems to be the case, the strictures of the Rule were no longer being adhered to. In many ways it might resemble that of the upper classes, although was probably not as cariogenic, and was certainly likely to be more cariogenic than that of the general population.

5 MATERIALS AND METHODS

5.1 Introduction.

This chapter describes the sources from which data were collected, how this was achieved, the details of the data recorded, and maps of the site distributions. It then discusses the division of sites into chronological periods, different contexts, locations and regions. Finally an outline of the way in which the results on dental caries prevalence are presented in Chapter 6 is given, together with details of the statistical methods used to test the significance of the results.

5.2 The Data Source: All Sites.

Only data from sites in England, Scotland and Wales were considered as Eire and Northern Ireland are mapped on a different national grid (the Irish National Grid System), which is difficult to link with the National Grid for Great Britain (Perkins and Parry, 1996; Owen and Pilbeam, 1992). Data for each sample were collected from both published and unpublished skeletal reports. Unpublished reports were accessed at the University of Bradford (originally the Calvin Wells Archive), University of Sheffield, Museum of London Specialist Services (MoLSS Archive), and through the English Heritage Ancient Monument Laboratory reports. The published skeletal reports were often found as appendices to the main site report, possibly with further detail included on microfiche. Other reports were published in a variety of journals, with or without information on the site itself. If a catalogue of the skeletal remains was included then this was also consulted. Data on the site itself was obtained from the site report, or from the skeletal report and any other published sources that could be traced if this was unavailable.

Eighty-eight sets of data with a total of 14,296 skeletons were collected from 79 sites. Fifteen data-sets were provided from six sites, which each had data-sets covering more than one period (see Table 5.2:1). For these reasons, these sites may appear more than once in subsequent tables and figures and are identified by unique data-set reference numbers. Appendix 1 lists all data-sets collected in alphabetical order of site name, showing the data-set number, location (town/county and grid reference), number of skeletons recovered, date range, period and references to the skeletal and site reports.

Table 5.2:1 Sites providing more than one data-set

Site	No. of data-sets provided	Data-set reference numbers shown by Medieval period		
		Early	Middle	Late
School Street, Ipswich/ Blackfriars, School Street, Ipswich	2		39	79
Golden Minster, Gloucester - A,B and C	3		22 (A)	63 (B); 65 (C)
Jarrow, Tyne and Wear – A and B	2	86 (A)		87 (B)
Rivenhall, Essex – A,B,C and D	4	64 (A)	73 (B)	74 (D); 83 (C)
St Andrews Fishergate, York – P4 and P6	2		61 (P4)	62 (P6)
Whithorn, Galloway – A and B	2	88 (B)		47 (A)

Initially, the intention was to divide the sites into two broad periods: Early and Late Medieval (see Figure 5.2:1)

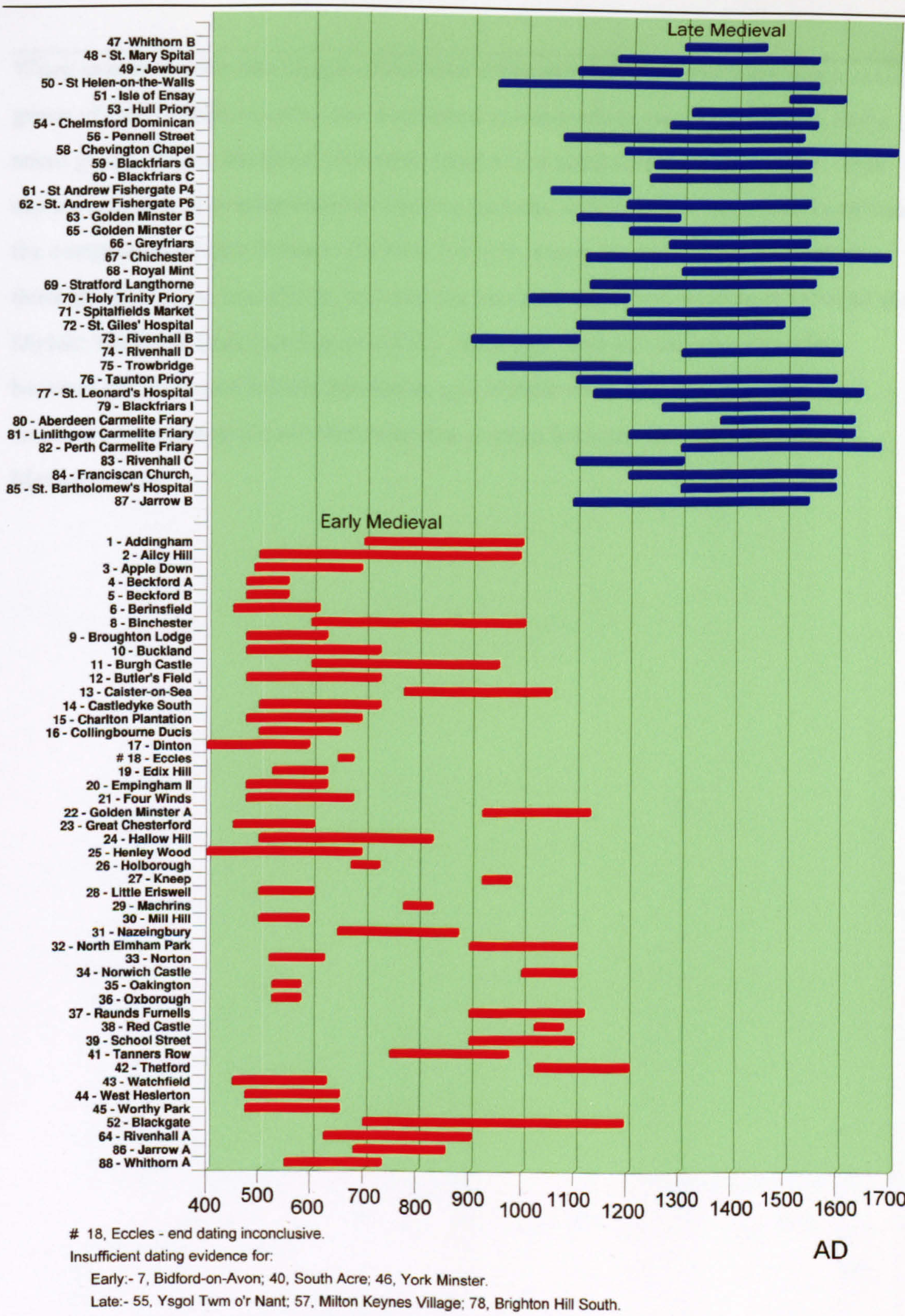
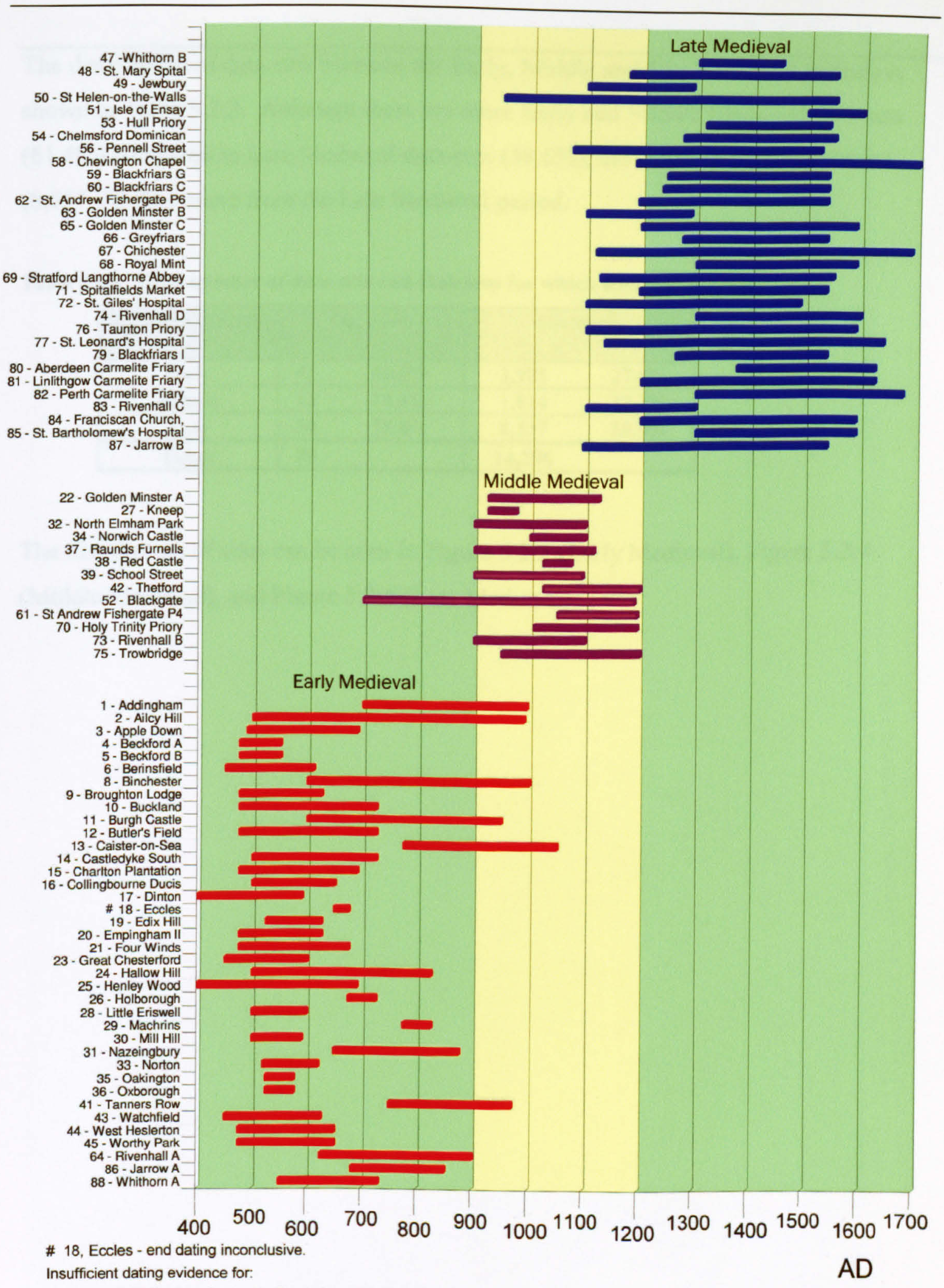


Figure 5.2:1 Chronological division of sites for which data was collected into two periods: Early Medieval and Late Medieval.

When examining the date ranges of the sites it became apparent that there was a small group of Early Medieval sites that were dated to the tenth-to-twelfth centuries, and a small group of Late Medieval sites also dated to the tenth-to-twelfth centuries. This caused a degree of overlap between the two periods, which, it was felt, would confuse the comparison of data between the two. For this reason it was decided to create a third group of sites, transitional between the two periods, which have been labelled the Middle Medieval sites (see Figure 5.2:2). Although there is a degree of overlap between the Early and Middle Medieval, and Middle and Late Medieval sites the creation of this group almost eliminates the overlap between the Early and Late Medieval sites.



18, Eccles - end dating inconclusive.

Insufficient dating evidence for:

Early:- 7, Bidford-on-Avon; 40, South Acre; 46, York Minster.

Late:- 55, Ysgol Twm o'r Nant; 57, Milton Keynes Village; 78, Brighton Hill South.

Figure 5.2:2 Chronological division of sites for which data was collected into three periods: Early Medieval, Middle Medieval and Late Medieval.

The distribution of data-sets between the Early, Middle and Late Medieval periods is shown in Table 5.2:2. Although there are more Early and Middle Medieval data-sets (61.4%) compared to Late Medieval data-sets (38.6%), the majority of the skeletons (8,557, 59.9%) come from the Late Medieval period.

Table 5.2:2 Total number of data-sets and skeletons for which data was collected.

Medieval Period	Data-sets		Skeletons	
Early	41	46.6%	3,925	27.5%
Middle	13	14.8%	1,814	12.7%
Late	34	38.6%	8,557	59.9%
Total:	**88**		**14,296**	

The distribution of sites can be seen in Figure 5.2:3 (Early Medieval), Figure 5.2:4 (Middle Medieval), and Figure 5.2:5 (Late Medieval).

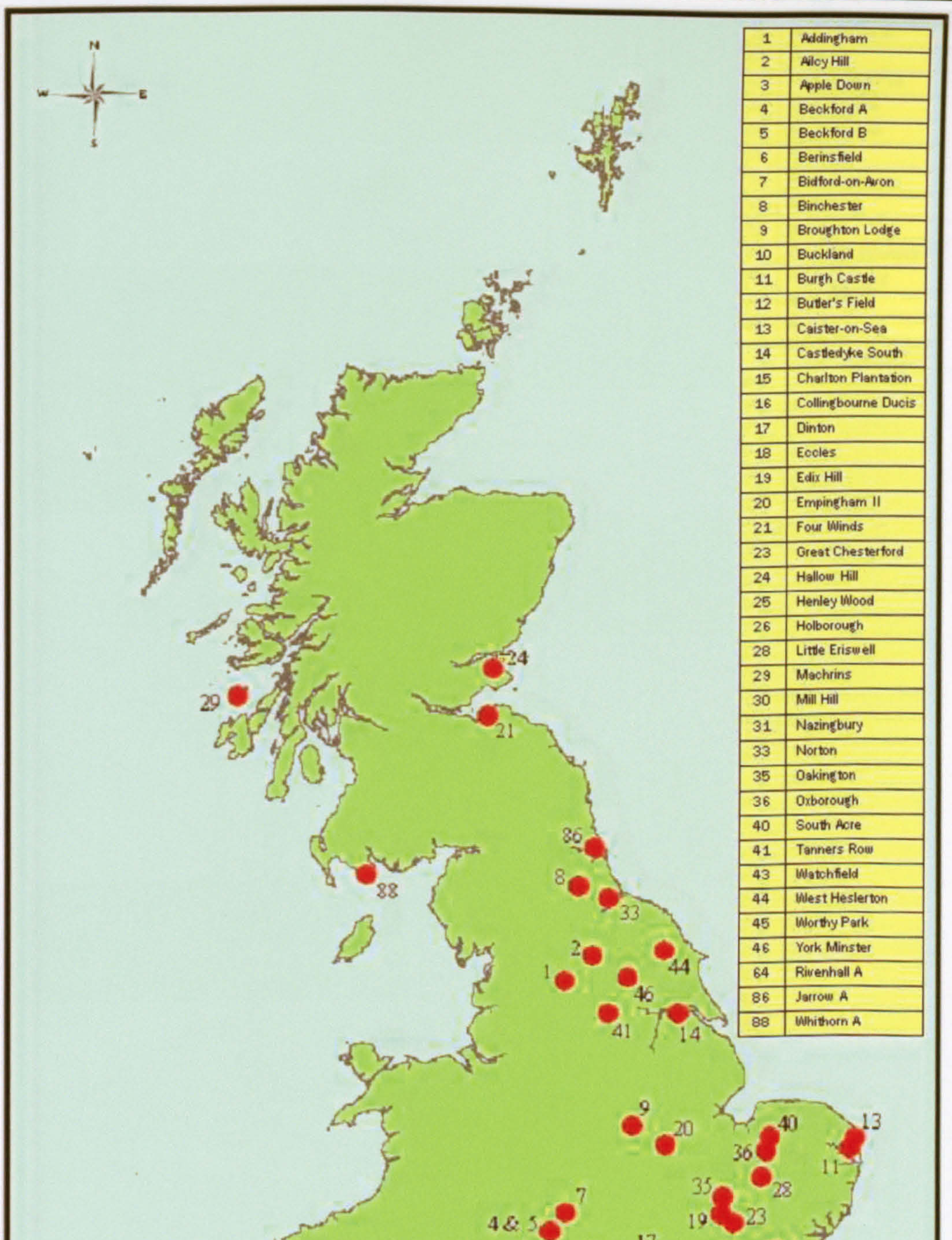


Figure 5.2:3 Map showing distribution of Early Medieval sites for which data was collected.

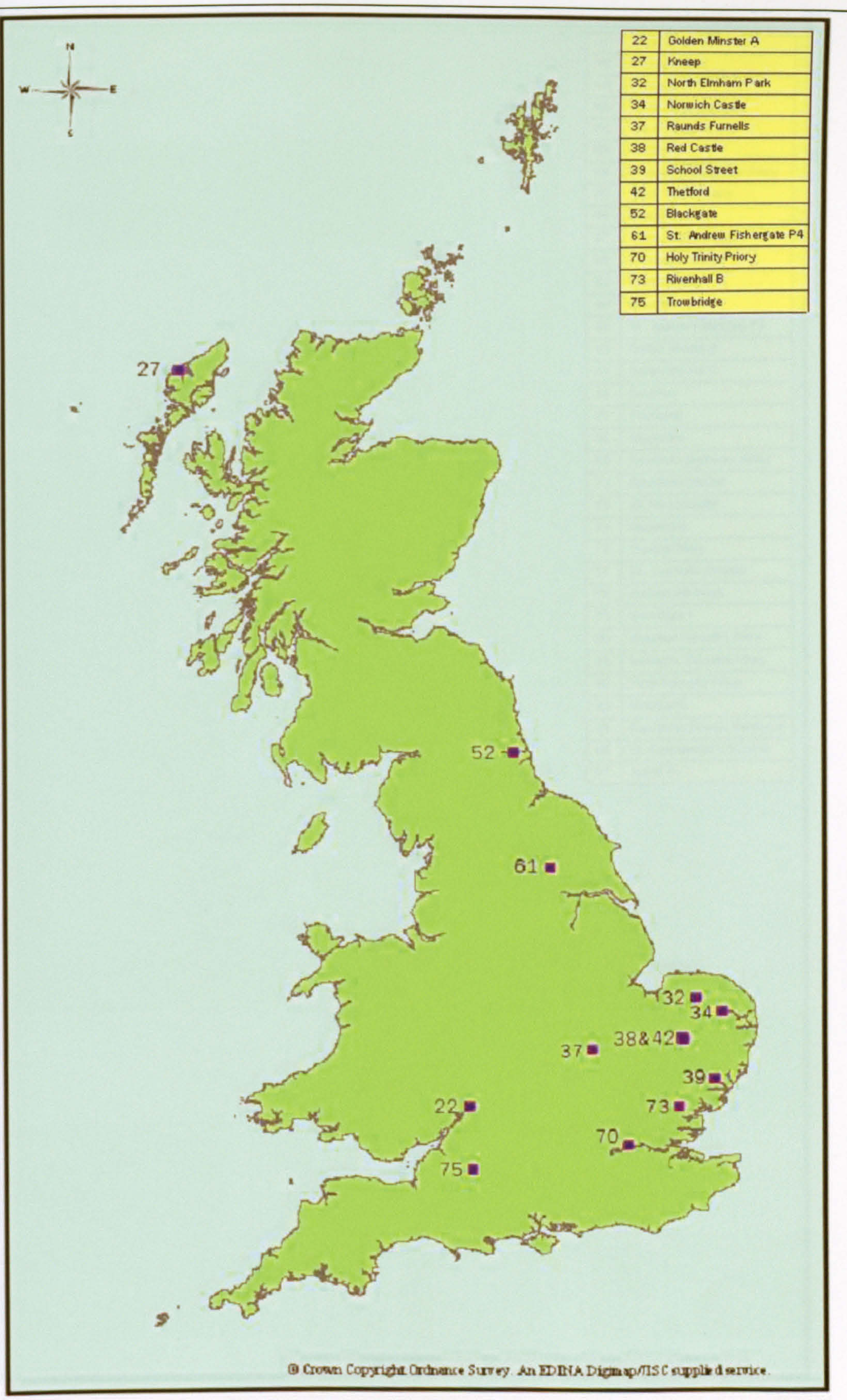


Figure 5.2:4 Map showing distribution of Middle Medieval sites for which data was collected.

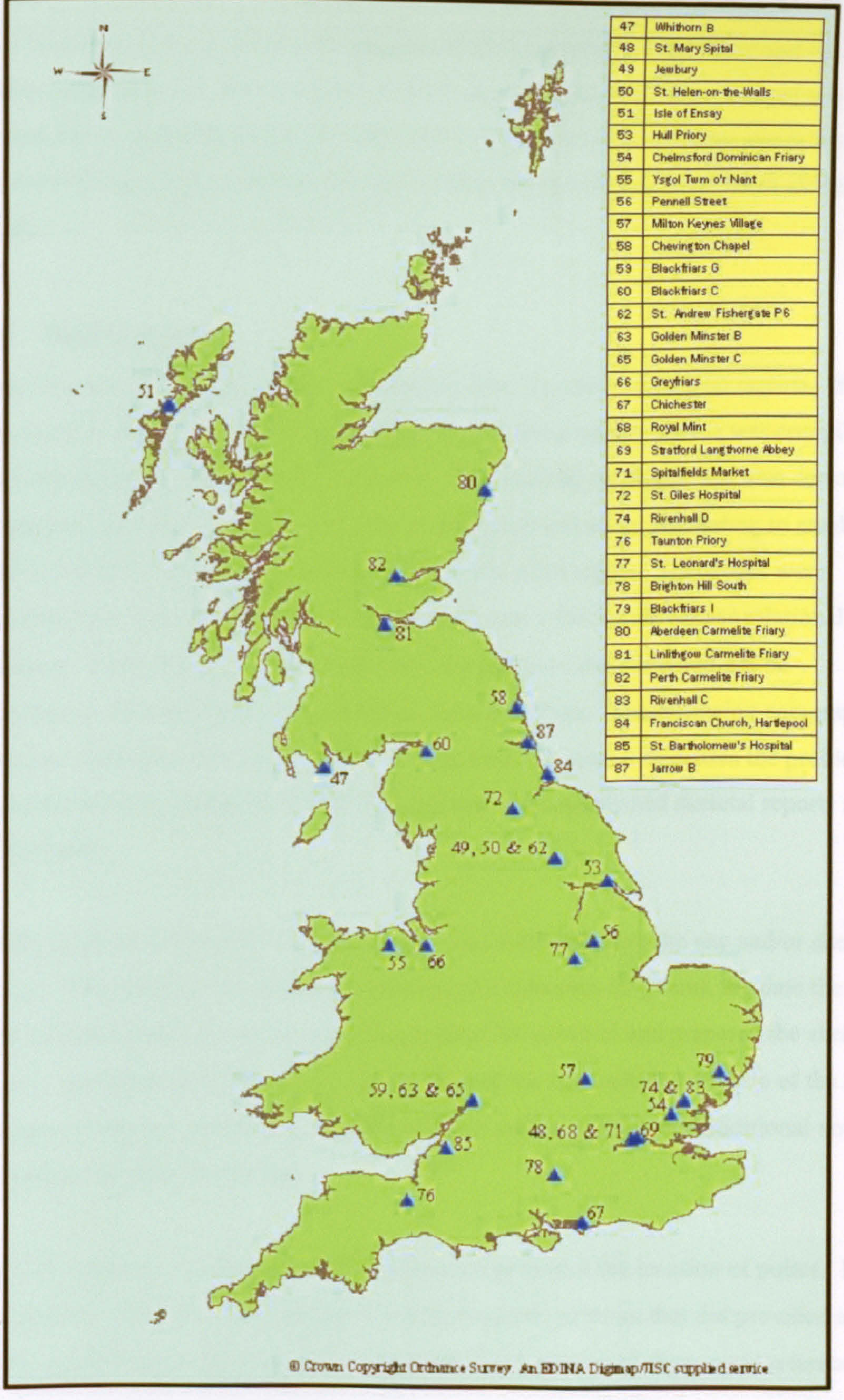


Figure 5.2:5 Map showing distribution of Late Medieval sites for which data was collected.

It is immediately apparent that the majority of sites, particularly the Early and Middle Medieval ones, are located towards the south and east of Britain. Few sites of any period can be found in the upland zones of the north and west; only one site is located in Wales (Ysgol Twm o'r Nant) and the Scottish sites tend to be distributed along the coast.

5.3 Data Collected.

Data for each site (or data-set) were collected from the site and skeletal reports. If a summary of the relevant data was not presented in these reports then it was compiled from the skeletal catalogue, where possible. The skeletal catalogue was also consulted to supplement the information provided in the report and when attempting to resolve discrepancies noted in the text and/or tables in the main report. These data were recorded on a form (see Appendix 2), and input into a Microsoft Access relational database. If data for any of the categories were not provided, or could not be ascertained, then the fields in the database were left blank. The following paragraphs describe what data were recorded and in what form; Chapter 8 discusses the problems encountered with the data available in published and unpublished skeletal reports in more detail.

Firstly, general information for each sample was collected from the site and/or skeletal report. This included the site name, address, grid reference (if given), the date the site was excavated, and the osteologists who studied the material and prepared the skeletal report. Information relating to the archaeology of the site included the date of the site, the type of site (i.e. public churchyard, monastic cemetery, etc.), and additional notes on points that seemed relevant.

ArcGIS requires a 12-figure grid reference in order to plot the location of points. Not all sites had supplied a grid reference, but the majority of those that did provided an eight- or a ten-figure grid reference. Only three had given a 12-figure grid reference, one had provided a six-figure grid reference, and three had omitted the letters defining the 100-kilometre National Grid squares but had provided the subsequent six digits. For those sites with less than a 12-figure grid reference, the required number of zeros was added to the end of the eastings and northings to produce a 12-figure grid reference. In addition, the letters referring to the 100-kilometre grid squares were replaced with their respective numbers. For example, the eight-figure grid reference TL 386 066 (Nazingbury) became 538600 206600, and the 10-figure grid reference SE 0846 4974 (Addingham) became 408460 449740. If a grid reference for the site was available in the report then this is listed in Appendix 1 shown in parenthesis below the full 12-figure grid reference.

The EDINA Digimap online gazetteer and the Archaeology Data Service online catalogue of archaeological sites were used to obtain grid references for the sites that lacked them. The Digimap gazetteer was used to find the grid references for the places where the sites were located. To assess the validity of this approach, Digimap was used to find grid references for the sites that already had grid references supplied in the reports, and the two were compared. The majority of the sites showed a 500-800m difference in location between the two grid references and all but two were below a 2 km difference. In the case of one of the latter (the site with the largest difference (3.8 km) between the grid reference supplied in the report and that obtained via Digimap), the nearest place given in the site report was stated to be three kilometres away from the site itself, so this large difference is not surprising. It was decided that this degree of error, although not ideal, was acceptable because the study was examining distributions across the whole of Britain and the scale would be small. At this level of resolution, errors in location in the region of 500-800m would be unnoticeable.

Secondly, data concerning the composition of the sample itself were collected, and this included: information on the preservation and completeness of the skeletons; the size of the sample; numbers of adults and subadults; numbers of males, females and unsexed adults; the numbers of individuals in the different age categories; and the mean, minimum and maximum stature estimates for the male and female adults.

Information on the condition of the skeletal remains was simply noted as it was described in the report. If a table displaying the numbers of skeletons in different preservation or completeness categories was present then this was recorded. The information given in the text of the report concerning the numbers of skeletons excavated and the distribution of individuals amongst the different age and sex categories was compared with the data given in any relevant tables. The numbers provided in these tables were totalled and compared with the totals printed in the tables, and cross-referenced with any other tables and the text. Discrepancies between different tables and between figures given in the tables and those discussed in the text were resolved as best as was possible. If a skeletal catalogue was provided, then this was consulted as an additional source of information. All discrepancies were noted.

The number of skeletons in the age categories given in the report was recorded based on the tables, text and skeletal catalogue (if required). In addition, the age used to separate adults and subadults was noted. Because the age categories into which the skeletons were divided varied considerably between reports (see Table 5.3:1) it was impossible to record the number of skeletons in exactly the same age categories for each site, which complicated the entry of data into the computer. Therefore, the categories given in the report were used as the basis for calculating the number of skeletons in broad age ranges. It was decided to divide the adults as best as possible into the following categories and to calculate the proportion of skeletons in each group:

- Young Adult (YA), c. 18-25;
- Young Middle Adult (YMA), c. 25-35;
- Old Middle Adult (OMA), c. 35-45;
- Old Adult (OA), c. 45+;
- Unaged Adult (UA), Adults who could not be aged.

These divisions were chosen as the majority of data-sets had used a variation of this categorisation. For some sites the youngest category contained individuals aged 15-25, 16-25, 17-25, 20-25 or even 18-30. Where adults had been divided into 20-30, 30-40, 40-50 and 50+ age categories, 20-30 was taken to be equivalent to YA, 30-40 as YMA, 40-50 as OMA, and 50+ as OA. For other sites, the number of skeletons in some categories had to be amalgamated, e.g. 15-20 and 20-25 were combined as YA, 25-30 and 30-35 were combined as YMA etc. When no summary data were given in the report, the skeletal catalogue was used as a source of data. In these cases the ages assigned to individual skeletons could be very idiosyncratic, and they had to be divided into the four age groups as best as possible. If an age range was particularly broad (e.g. 25-45) then the individual was counted as UA. It is appreciated that this is not an ideal situation, but is hoped that this will provide a general indication of the age structure of the adult population that will facilitate the comparison of disease data between sites.

The number of male, female and unsexed adults was recorded. Several reports had sexed subadults, and where this had occurred it was attempted to exclude them from the total of the sexed individuals. If a report had possible males and possible females as sex categories, then these were combined with the individuals in the male and female categories respectively. Where confusion existed in the report as to the numbers of males and females, the skeletal catalogue (if provided) was consulted.

Table 5.3:1 Different age ranges used by different data-sets.

17-25	25-35	35-45	45-60	60+			
17-25	25-35	35-45	45+				
20-25	26-35	36-45	46+	25+			
18-25	26-35	36-45	45+	Adult			
18-25	25-35	35-45	45+	Adult			
18-25	25-35	35-45	45-55	55+	Adult		
15-20	20-25	25-30	30-35	35-40	40-45	45-50	50+
18-25	Young Adult	Middle Adult	Old Adult	Adult			
Under 35	Over 35						
25-35	35-45	45+	Adult				
16-25	26-35	36-45	46-55	55+	Elderly	Adult	
Young	Middle	Mature					
20-30	30-40	40-50	50+	Adult			
18-27	28-37	38-47	48+	Adult	25+		
17-25	26-35	36-45	46+	25+			
15-20	20-25	25-30	30-35	35-40	40+	Adult	
18-25	25-35	35-45	45-50	50+			
15-25	25-35	35-45	45+	Adult			
17-25	25-35	34-45	45+	Adult			
20-30	Over 30						
Young	Adult	Mature	Grown				
18-25	26-35	36-45	46-60	61+			
17-25	25-35	35+					
18-29	30-39	40-49					

The mean, minimum and maximum statures of the males and females in each population were recorded in centimetres, along with the number of males and females for whom stature could be calculated, and the formula used for stature calculation. Where stature had been given in feet and inches only, this was converted to centimetres. If means and ranges were not provided in the report then the stature of each skeleton in the catalogue (if available) was collected and the means and ranges for males and females were calculated. A few sites had provided stature estimates for unsexed individuals, but these were excluded from the data collection.

Finally, data on a number of diseases that affect the skeleton were collected, and these included: dental caries, dental enamel hypoplasia, infectious disease (non-specific infection, leprosy, tuberculosis and treponemal disease), joint disease (spinal and non-spinal osteoarthritis, Diffuse Idiopathic Skeletal Hyperostosis (DISH), ankylosing spondylitis, gout and rheumatoid arthritis), fractures sustained by different areas of the body (cranium, torso, upper & lower limbs), spondylolysis, metabolic disease (cribra orbitalia, rickets, scurvy and osteoporosis), congenital disease (spina bifida, vertebral anomalies and cleft palate), neoplastic disease, endocrine disease, and Paget's disease. Again, these data were collected from the skeletal report, and if a skeletal catalogue was available then this was used to help resolve instances where the data were unclear or relevant data were not provided.

Although it would have been preferable to collect information on the number of elements affected and the number of elements it was possible to observe for the condition to enable the calculation of actual prevalence rates for a disease, it soon became apparent that few of the reports provided this information. For this reason, for the majority of the pathological conditions, the number of individuals affected had to be recorded, and a crude prevalence calculated based on the number of individuals (or adults/subadults, males/females) present in the sample. The total number of individuals with a pathological condition was recorded, as was the number of adults and subadults, males and females if this information was given.

It was decided to focus on dental caries, as this was the best data presented in the skeletal reports. Two forms of data on dental caries were recorded. Firstly, as for the other disease categories, the number of individuals (in total, and also males, females, adults and subadults) with dental caries was recorded. If the number of individuals with dentitions available for examination was stated then this was also noted, meaning that the prevalence of caries amongst individuals could then be calculated as a proportion of individuals with dentitions. Secondly, the number of teeth present and the number of teeth with caries were recorded. This was recorded for deciduous and permanent teeth, for teeth from adults and teeth from subadults, and for teeth from males and teeth from females. The prevalence of caries could then be calculated as the number of teeth with caries divided by the number of teeth present.

5.4 Sites with Data on Dental Caries.

The sites with data on dental caries were assessed in order to establish the type of data provided for each data-set, i.e. whether the data related to individuals, teeth or both, and which groups of individuals or teeth were represented. The results of this process are discussed further in Section 6.1, and the type of data provided for each data-set, whether for teeth, skeletons, both or neither, is given in Appendix 3.

Following these results, it was decided to focus analysis on the data for teeth from adults, males and females, as this was the form of data provided for the majority of sites that had data on dental caries. If a site provided data for the number of teeth present and with caries from males and females, but not from adults, then the male and female teeth present and those with caries were combined in order to provide a total number of teeth for adults. In some skeletal reports it was stated that the teeth from adults included sexed adults only. All the data-sets that provided data on caries prevalence in teeth from adults are listed in Appendix 4, together with whether they provided data on teeth from males and/or females, or data on caries prevalence in individuals. Those data-sets where the data for teeth from adults are for sexed adults only are marked with an asterisk. Four data-sets were discarded from further analysis: Kneep and Machrins because each only had one skeleton, Oxborough because the data on caries prevalence was unclear, and Ysgol Twm o'r Nant because the skeletons were all disarticulated and very little was known of the context of the site. The final data-sets selected for further analysis are listed in Appendix 5, and all further analysis relates to these sites only, unless otherwise stated.

Table 5.4:1 shows the number of selected sites and data-sets providing data for each period, and in total, on teeth from adults, males and females. All selected data-sets (53) provided data on caries prevalence in teeth from adults. The number of data-sets for the Early and Late Medieval periods was almost equal at 23 and 21 respectively, but there were only 9 data-sets for the Middle Medieval period. The total number of skeletons from these sites was 9,136 (including 146 skeletons from Isle of Ensay), with 3,419 for the Early Medieval period, 1,739 for the Middle Medieval period, and

3,978 (including 146 skeletons from Isle of Ensay) for the Late Medieval period. Of these 53 data-sets, 41 provided data on teeth from males and females. The number of data-sets, and male and female skeletons, for each period is shown in Table 5.4:1. Table 5.4:1 also shows the number of selected data-sets that also provide data on teeth from subadults (permanent, deciduous and both together), and on all permanent teeth (from adults and subadults combined).

Table 5.4:1 Sites selected with data on caries prevalence in teeth.

Medieval Period	Sites Selected	%	Data-sets Selected	%	Skeletons	%
Sites with data on caries prevalence in teeth from adults						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Adults)**	**%**
Early	23	50.0%	23	43.4%	3,419	38.0%
Middle	9	19.6%	9	17.0%	1,739	19.3%
Late	20	43.4%	21	39.6%	3,832?	42.6%
Total:	46†		53		8,990?	
Sites with data on caries prevalence in teeth from males						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Males)**	**%**
Early	19	54.3%	19	46.3%	609	30.8%
Middle	6	17.1%	6	14.6%	308	15.6%
Late	15	42.9%	16	39.0%	1,062	53.7%
Total:	35‡		41		1,979	
Sites with data on caries prevalence in teeth from females						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Females)**	**%**
Early	19	54.3%	19	46.3%	604	41.8%
Middle	6	17.1%	6	14.6%	250	17.3%
Late	15	42.9%	16	39.0%	590	40.9%
Total:	35‡		41		1,444	
Sites with data on caries prevalence in teeth from subadults (P + D)						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Subadults)**	**%**
Early	12	52.2%	12	44.4%	337	25.8%
Middle	4	17.4%	4	14.8%	125	9.6%
Late	10	43.5%	11	40.7%	844	64.6%
Total:	23§		27		1,306	
Sites with data on caries prevalence in deciduous teeth from subadults						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Subadults)**	**%**
Early	12	52.2%	12	50.0%	422	29.2%
Middle	3	13.0%	3	12.5%	127	8.8%
Late	9	39.1%	9	37.5%	896	62.0%
Total:	23¤		24		1,445	
Sites with data on caries prevalence in permanent teeth from subadults						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (Subadults)**	**%**
Early	12	57.1%	12	54.5%	355	28.7%
Middle	2	9.5%	2	9.1%	86	7.0%
Late	8	38.1%	8	36.4%	796	64.3%
Total:	21¤		22		1,237	
Sites with data on caries prevalence in permanent teeth (subadults & adults)						
Medieval Period	**Sites Selected**	**%**	**Data-sets Selected**	**%**	**Skeletons (All)**	**%**
Early	15	62.5%	15	57.7%	1,494	30.7%
Middle	2	8.3%	2	7.7%	226	4.7%
Late	9	37.5%	9	34.6%	3,139	64.6%
Total:	24§		26		4,859	

† Five sites contributed data for more than one period but have only been counted once.
‡ Four sites contributed data for more than one period but have only been counted once.
§ Two sites contributed data for more than one period but have only been counted once.
¤ One site contributed data for more than one period but has only been counted once.
?Totals exclude Isle of Ensay skeletons as no data on the number of adults and subadults was given.

The sites were subdivided into different groups to investigate chronological trends, regional differences, coastal and inland differences, and any differences between monastic, hospital and non-monastic sites.

5.5 Chronological Division.

The broad division of sites into Early, Middle and Late Medieval has been described above. However, these periods, particularly the Early and Late Medieval periods, cover lengthy time spans, so it was felt that a further chronological division of sites within these categories should be attempted. This division was based on the dates given for the cemetery in the site or skeletal report. The terms chosen to describe these sub-periods were problematic, as labels such as "Early Early Medieval" or "Early-Middle Early Medieval" were considered to be too confusing and unwieldy. For this reason alone, the Early Medieval sub-periods, and one Middle Medieval sub-period, were labelled as different relative periods of 'Saxon'. Although it is recognised that this term should refer to sites in the south and east of England only (Hills, 1999), it has been used in this study to refer to sites from Britain as a whole simply for the purpose of achieving a less confusing terminology; no ethnic connotation is intended by the use of this term.

The Early Medieval period was divided into two Group Sub-Periods, labelled the Early Saxon/Early-Middle Saxon (ES/EMS) and the Middle Saxon/Middle-Late Saxon (MS/MLS) (see Figure 5.5:1).

There seemed to be a definite chronological division between the two groups, although there was some degree of overlap in the seventh and eighth centuries. The Early Saxon/Early-Middle Saxon group comprised those sites that dated between the early/mid-fifth century and the late-seventh/early-eighth century. The Middle Saxon/Middle-Late Saxon group included those sites whose dates ranged from the mid/late-seventh century to the mid-eleventh century. A further attempt was made to subdivide these two groups, although the degree of overlap between these extra sub-divisions was much greater. The Early Saxon/Early-Middle Saxon group was divided into Early Saxon (ES) sites, dating from the early/mid-fifth century to the mid-seventh century, and Early-Middle Saxon sites (EMS), dating from the mid/late-fifth century to the late-seventh/early-eighth century (see Figure 5.5:1). The Middle Saxon/Middle-Late Saxon group was divided into Middle Saxon (MS) sites, dating from the mid/late-seventh century to the mid/late-ninth century, and Middle-Late Saxon (MLS) sites, dating from the mid-eighth to mid-eleventh century, thus forming four Divided Sub-Periods (see Figure 5.5:1).

Early Medieval Main Period (EM)	**Early Saxon/ Early-Middle Saxon** Group Sub-Period (ES/EMS)	**Early Saxon** Divided Sub-Period (ES)	**early/mid 5th C to mid 7th C**
		Early-Middle Saxon Divided Sub-Period (EMS)	**mid/late 5th C to late 7th/early 8th C**
	Middle Saxon/ Middle-Late Saxon Group Sub-Period (MS/MLS)	**Middle Saxon** Divided Sub-Period (MS)	**mid/late 7th C to mid/late 9th C**
		Middle-Late Saxon Divided Sub-Period (MLS)	**mid 8th C to mid 11th C**
Middle Medieval Main Period (MM)	**Late Saxon** Sub-Period (LS)		**early 10th C to late 12th C**
	Early-Late Medieval Sub-Period (ELM)		**mid 10th C to late 12th C**
Late Medieval Main Period (LM)			**late 11th/ early 12th C to mid 16th C**

Figure 5.5:1 Division of the Medieval Period into sub-periods.

The Middle Medieval period was divided into Late Saxon (those sites originally classed as Early Medieval based on the interpretations in the site reports) and Early Late Medieval (those sites originally classed as Late Medieval). This meant that the similarities of the two groups of sites, beyond date, could be investigated. Although the cemetery at Thetford dates to the eleventh-to-twelfth centuries, the site was described as Late Saxon/Saxo-Norman in the site and skeletal reports and so it has been included in the Late Saxon group.

Unfortunately, as the Late Medieval cemeteries were in use for long periods of time, and for most sites the skeletons had not been subdivided into different phases, it was impossible to separate the Late Medieval period into any further chronological sub-groups.

The chronological division of the sites selected for analysis is shown in Figure 5.5:2.

Caries prevalence was established for each main period and sub-period, and the results compared to examine any chronological changes in caries prevalence.

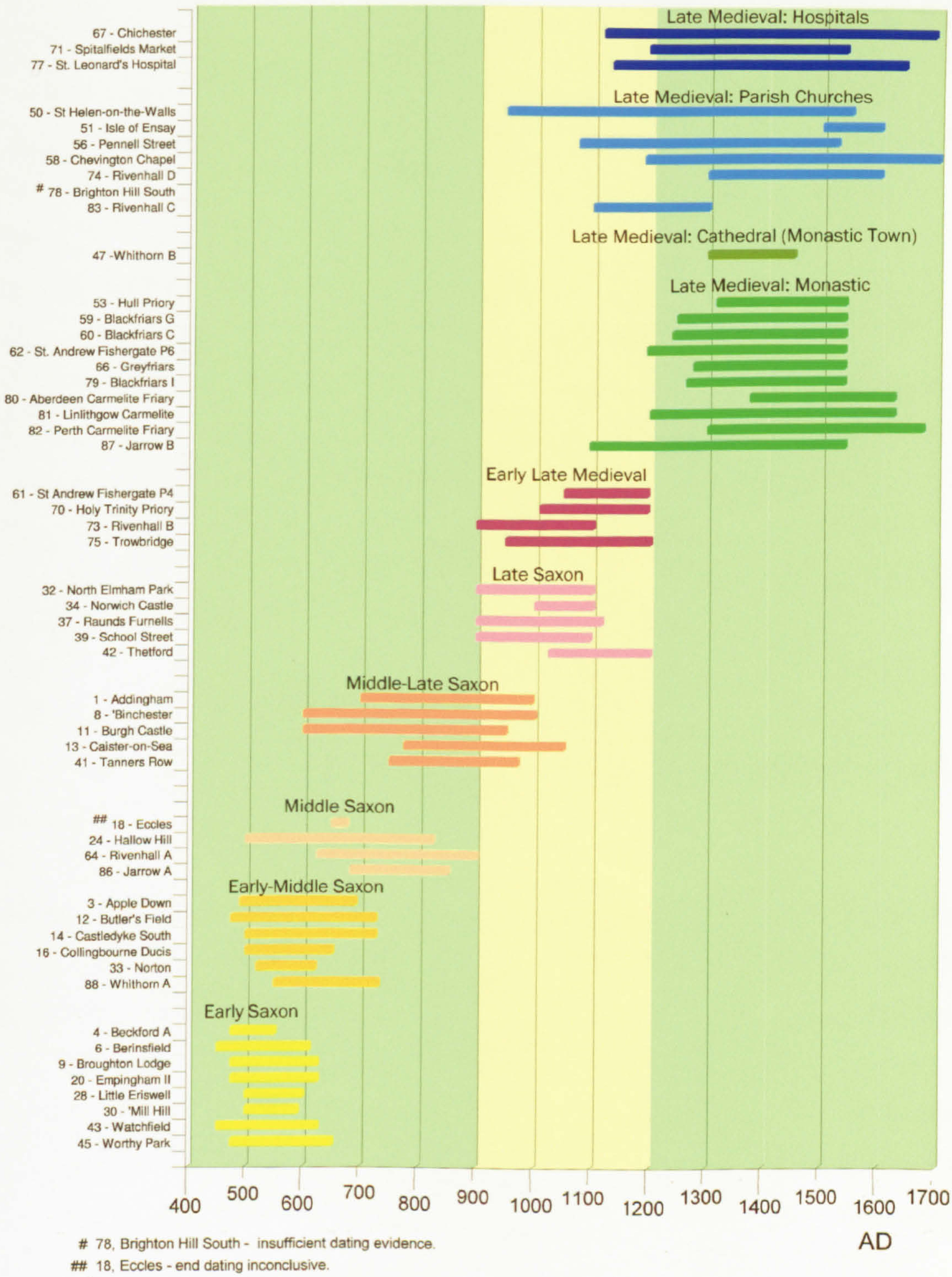


Figure 5.5:2 Chronological division of sites selected for analysis into different sub-periods.

5.6 Cemetery Types.

As discussed above, it was impossible to divide the Late Medieval data-sets into any smaller chronological periods. However, it was possible to divide them into four different types: church cemeteries, monastic cemeteries, hospital cemeteries and a cathedral cemetery (see Figure 5.5:2). This division was based on the interpretation of the site given in the site and/or skeletal report. Church cemeteries included those sites associated with a parish or private church. Monastic cemeteries encompassed those associated with friaries or monasteries. There is some degree of overlap between the monastic and hospital categories, as hospitals tended to be run by monasteries, but 'hospital cemeteries' were only identified as such when a site was specifically known to have been running a hospital. The 'cathedral' category was created for Whithorn B, Galloway. Originally a monastic site, by the thirteenth/fourteenth centuries the town had achieved a separate identity from the monastery, yet the two remained closely dependent on each other. The monastery acted as a focus for pilgrimage and sustained the development of the town, so the cathedral cemetery served a broader population than just the local population (Hill, 1997). For these reasons it was felt that Whithorn B could be classed as neither a church cemetery nor a monastic cemetery, and since the number of skeletons excavated from the site was large (1605) it could be classed in a category of its own.

Different groups of people were likely to have been buried in each type of site, and so the caries prevalence rate for each cemetery type was calculated and compared in order to examine any differences between them. Burials excavated from church cemeteries probably represent the majority of the population, who had little opportunity to be buried elsewhere (Daniell, 1997; Morgan, 1999). Those buried within the church were more likely to be of higher status, often founders or benefactors and locally important families (Horrox, 1999). Although initially the Church had forbidden the burial of lay people inside the church the practice became more common, until, by the fifteenth century, burial within the church extended to a wider assortment of people of varying status (Daniell, 1997).

Monastic cemeteries would have included the burials of the monks/friars/canons, many of whom would have come from an upper class background, and who, in theory, lived by a specific Rule governing daily life (Aston, 2000). The strictures of the Rule were likely adhered to in the earlier phases of the religious houses, but, as time wore on, more and more ways were found to evade many of the regulations (Harvey, B., 1993). The monasteries and friaries were also the desired burial places for high status individuals, especially wealthy benefactors and their families (Horrox, 1999; Daniell and Thompson, 1999; Daniell, 1997). It is also possible that religious houses were providing some kind of care for the sick, poor or elderly, some will have accommodated corrodians, “lay people who paid, or were sponsored, to lodge in private accommodation within a monastic precinct” (Gilchrist, 1995: p226), and they also would have provided shelter for travellers. Any of these groups may have been buried in the cemetery.

Those buried in hospital cemeteries would have included the inmates of the hospital, the staff who cared for them and managed the institution (brethren, sisters, and servants), and wealthy benefactors and their families (Gilchrist, 1995). The inmates would have varied according to the type of hospital. Some provided care (spiritual and physical) for the sick poor; others were leposaria, for the benefit of those suffering from leprosy; some acted as almshouses for the elderly or infirm, possibly accommodating specific groups of individuals such as elderly priests; and others functioned as hospices, offering hospitality for pilgrims and travellers (Gilchrist, 1995). In many cases these functions overlapped, with hospitals acting in several roles. Like the other religious houses, those residing within hospitals lived according to a Rule, and some took in corrodians.

5.7 Monastic and Non-Monastic Sites: Early Medieval; Middle Medieval; Late Medieval.

The Late Medieval church cemeteries were compared with the non-monastic sites from the Early and Middle Medieval periods. The term ‘non-monastic’ was used for the Early and Middle Medieval periods because church cemeteries are not established as the normal place of burial until the eleventh century (Daniell and Thompson, 1999). The intention in comparing the non-monastic and church sites was to compare caries prevalence in the general population between the three periods. In addition, the Late Medieval monastic sites were compared with the monastic sites from the Early and Middle Medieval periods so that chronological trends in these specialised types of site could be studied and compared with that of the non-monastic sites.

5.8 Late Medieval Monastic Orders.

Several different religious orders existed in Medieval Britain, each with their own set of ideals and possibly following different Rules, which governed diet (Aston, 2000). The Late Medieval period was the only period with enough monastic sites to make a division into different types of order worthwhile. Therefore, the Late Medieval monastic sites were divided into different religious orders, so that their caries prevalence might be compared. The orders represented by the Late Medieval data-sets comprised: Augustinian (or Austin) friars (1 data-set), Benedictine monks (1 data-set), Carmelite friars (3 data-sets), Dominican friars (4 data-sets), and Gilbertine canons (1 data-set).

5.9 Location: Coastal and Inland.

High levels of fluoride are found in marine fish, and people who consumed a large quantity of marine foodstuffs might therefore be afforded some extra protection against dental caries. In the Early Medieval period it is likely that only people residing near the coast would have been able to exploit marine resources on a regular basis. The deep-sea fishing industry began to develop in earnest around the eleventh century, and, with the development of trade networks across the country, marine fish became available to people far inland (Enghoff, 2000; Aston, 1988; Bond, 2004).

The data-sets of each period were divided into those located on, or within c. 5 kilometres of, the coast, and those located further inland. In the Early Medieval period the coastal data-sets might be expected to display a lower caries prevalence rate than those inland, but this difference would be expected to disappear in the Middle and Late Medieval periods, as marine fish become more freely available and traded inland.

5.10 Regional Division.

Differences in caries prevalence exist in Britain today, with Scotland and northern areas of England suffering much higher prevalence rates than those seen in the south (Kelly, *et al.*, 2000). With little attention paid to possible regional differences in the past, it seemed logical to examine different areas of Britain to see whether such differences existed. The data-sets were divided into five regions (see Figure 5.10:1). The Far North (FN) encompassed all of Scotland and the far north of England. The

North/North West (N/NW) area covered the north and west of England. The Eastern/Central Eastern (E/CE) region included those sites located in modern East Anglia and the east midlands. The Central Southern (CS) group included a collection of sites located in the centre and south of England. Finally, the South East (SE) encompassed sites located in the south east of England.

The caries prevalence for each region was compared for each period, and then chronological changes in caries prevalence within each region were examined.

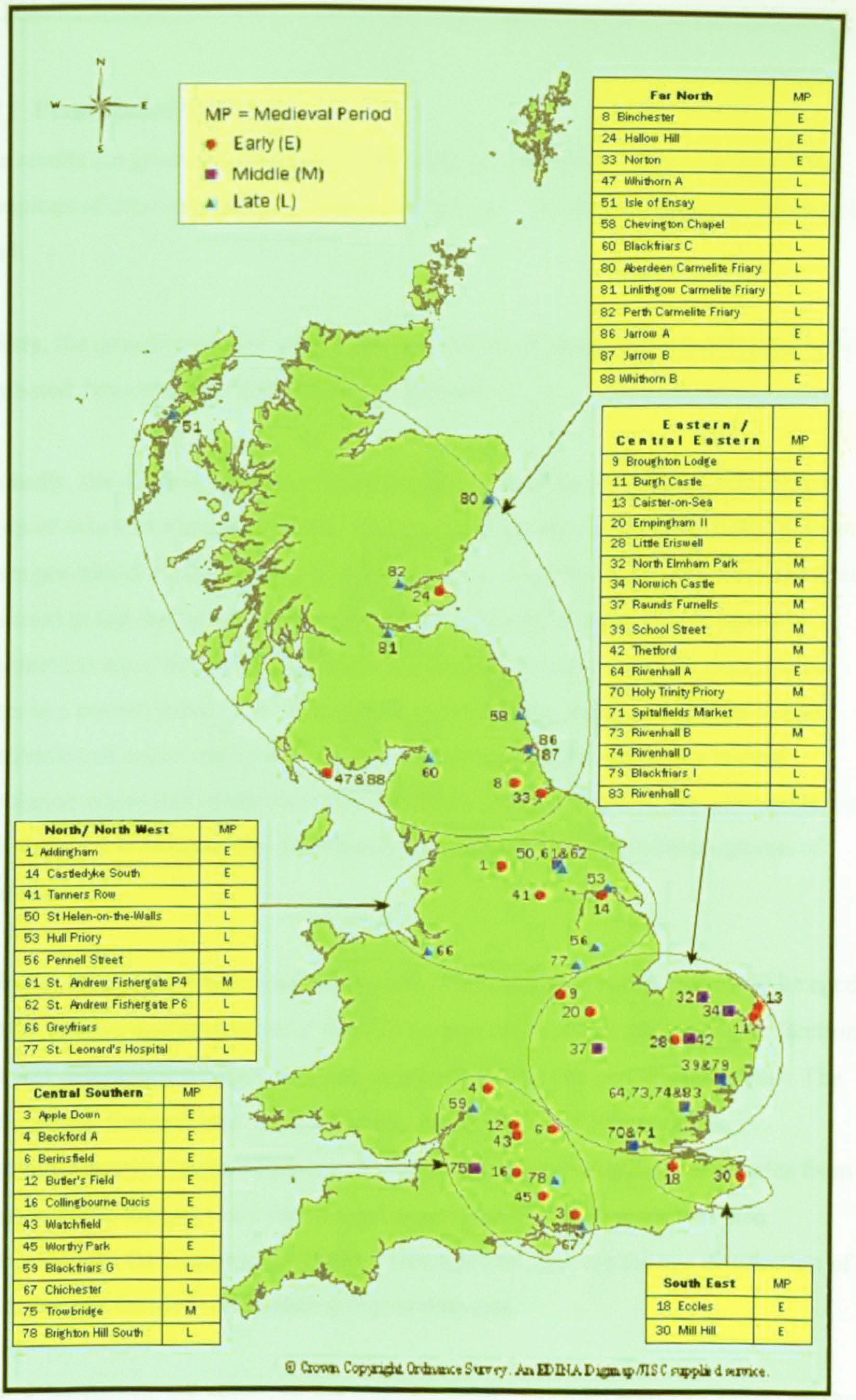


Figure 5.10:1 Map showing regional distribution of sites selected for analysis.

5.11 Presentation of Results.

The results are given in Chapter 6. Each section of the results deals with one of the groupings of data-sets described above, and for each section the following structure is used:

Firstly, the sample size, and number and proportion of adults and subadults, from the combined data-sets in each group were calculated.

Secondly, the number and proportion of males, females and unsexed adults in each group of data-sets were determined, but only for those data-sets that provided data on caries prevalence in teeth from males and females. The chi-square goodness of fit test was used to test the actual number of males and females in each sample against a hypothetical equal distribution of males and females, such as might be expected to occur in a normal population. The null hypothesis being tested was that the actual distribution of males and females was not significantly different from a normal population where half of the individuals are male and half female. The chi-square test was also used to compare the distribution of males and females between groups of data-sets.

Thirdly, the age distribution was examined. The number of adults that could be aged, and the number and proportion of these in each of the four age categories (see Section 5.3) was determined for the combined data from all the data-sets in each group. The Kolmogorov-Smirnov test was used to test for significant differences in age distribution between pairs of groups. The age distribution of males and females from those data-sets that provided data on caries prevalence in both sexes was also calculated, and the Kolmogorov-Smirnov test used to compare the age distribution of the males and females within each group of data-sets.

Lastly, the data on caries prevalence was presented. The total number of teeth present and the total number of teeth with caries for each group of data-sets was calculated, and these figures used were to work out the prevalence rate (n teeth with caries/ n teeth present). This process was carried out for teeth from adults, males and females.

Summary tables in the text only include the total number of teeth present, teeth with caries and prevalence rate for each group of data-sets, but the raw data can be found in the relevant appendices. The chi-square test was used to test for significant differences between the prevalence rates, comparing the actual number of teeth with caries and the number of teeth without with the distribution expected to occur by chance if both samples were the same.

Information on the statistical tests used were obtained from Shennan (1997), Madrigal (1995) and Fletcher and Lock (1991), and the tests themselves were carried out in the spreadsheet program Microsoft Excel. The data on proportions of adults and subadults, and sex and age distribution provide information on the demography of the samples. This can be useful in determining whether a cross-section of the population is being studied, or whether a specific group of individuals is being dealt with. The age distribution was also important in evaluating caries prevalence. Caries is associated with age, so a sample with a large proportion of older individuals would be expected to have a higher caries prevalence rate than one that consisted primarily of younger individuals.

6 RESULTS

The first section of this chapter concerns the type of data on dental caries provided by the data-sets; it describes the proportions of data-sets in total, and for each period. These sets of data led to the selection of certain categories of caries data for more detailed analysis. The definition of 'adult' as used within skeletal reports was investigated through the age at death chosen to divide adults and subadults. The chapter then progresses to an investigation of caries prevalence. Chronological periods are compared, beginning with the general division of the data-sets into three periods: Early, Middle and Late Medieval, followed by a comparison of sub-periods within the Early and Middle Medieval periods. The Late Medieval data-sets are divided into different site types: church, monastic, hospital and cathedral. This is followed by an investigation of caries prevalence in non-monastic and monastic sites across the three main periods, and a more detailed study of the Late Medieval sites of different monastic orders. The data-sets for each period are divided into those located on the coast and those located inland. Finally the data-sets are divided into five regions. For each stage of investigation listed above, the proportion of adults and subadults; males, females and unsexed adults; and individuals in different age categories for each group are given. This is followed by the results on caries prevalence in teeth from adults, males and females.

6.1 Evidence of Dental Caries in Skeletal Reports.

The first step in analysis was to establish which of the sites had data on dental caries and what form that data took. Table 6.1:1 shows the number of data-sets for each period (and in total) that had some form of data on caries prevalence, whether for teeth, individuals or both, and the number that had no data on caries prevalence at all.

Overall, 84.1% of the data-sets provided caries prevalence data of some kind, and the proportion was comparable for the Early and Late Medieval sites at 80.5% and 82.4% respectively. The Middle Medieval data-sets all provided prevalence data in some form. However, the type of data provided by each data-set varied: some provided data for teeth, some for individuals and some provided data for both. Table 6.1:2 shows the number of data-sets that gave some form of data on caries prevalence in teeth, individuals or both together; it also shows these data-sets as a percentage of both the total data-sets (%T) and the number of data-sets with dental caries prevalence data (%WCD). For information on the type of data provided for individual data-sets, see Appendix 3: All Sites; Appendix 4: Sites with data on the prevalence of caries in teeth; and Appendix 5: Sites used.

Table 6.1:1 Number of data-sets with and without data on caries prevalence.

Medieval Period	Data-sets				
	Total	With caries prevalence data (% in teeth and/or Skeletons)		Lacking caries prevalence data	
Early	41	33	80.5%	8	19.5%
Middle	13	13	100.0%	0	0.0%
Late	34	28	82.4%	6	17.6%
Total	88	74	84.1%	14	15.9%

Table 6.1:2 Number of data-sets with data on caries prevalence in teeth, individuals and both.

Medieval Period	Number of Data-sets		Data-sets with Caries Prevalence for:								
			Teeth			Skeletons			Both		
	T	WCD	n	%T	%WCD	n	%T	%WCD	n	%T	%WCD
Early	41	33	32	78.0%	97.0%	23	56.1%	67.9%	22	53.7%	66.7%
Middle	13	13	12	92.3%	92.3%	11	84.6%	84.6%	10	76.9%	76.9%
Late	34	28	24	70.6%	85.7%	22	64.7%	78.6%	18	52.9%	64.3%
Total	88	74	68	77.3%	91.9%	56	63.6%	75.7%	50	56.8%	67.6%

T = Total Data-sets; **WCD** = Data-sets With Caries Data; **n** = Number.

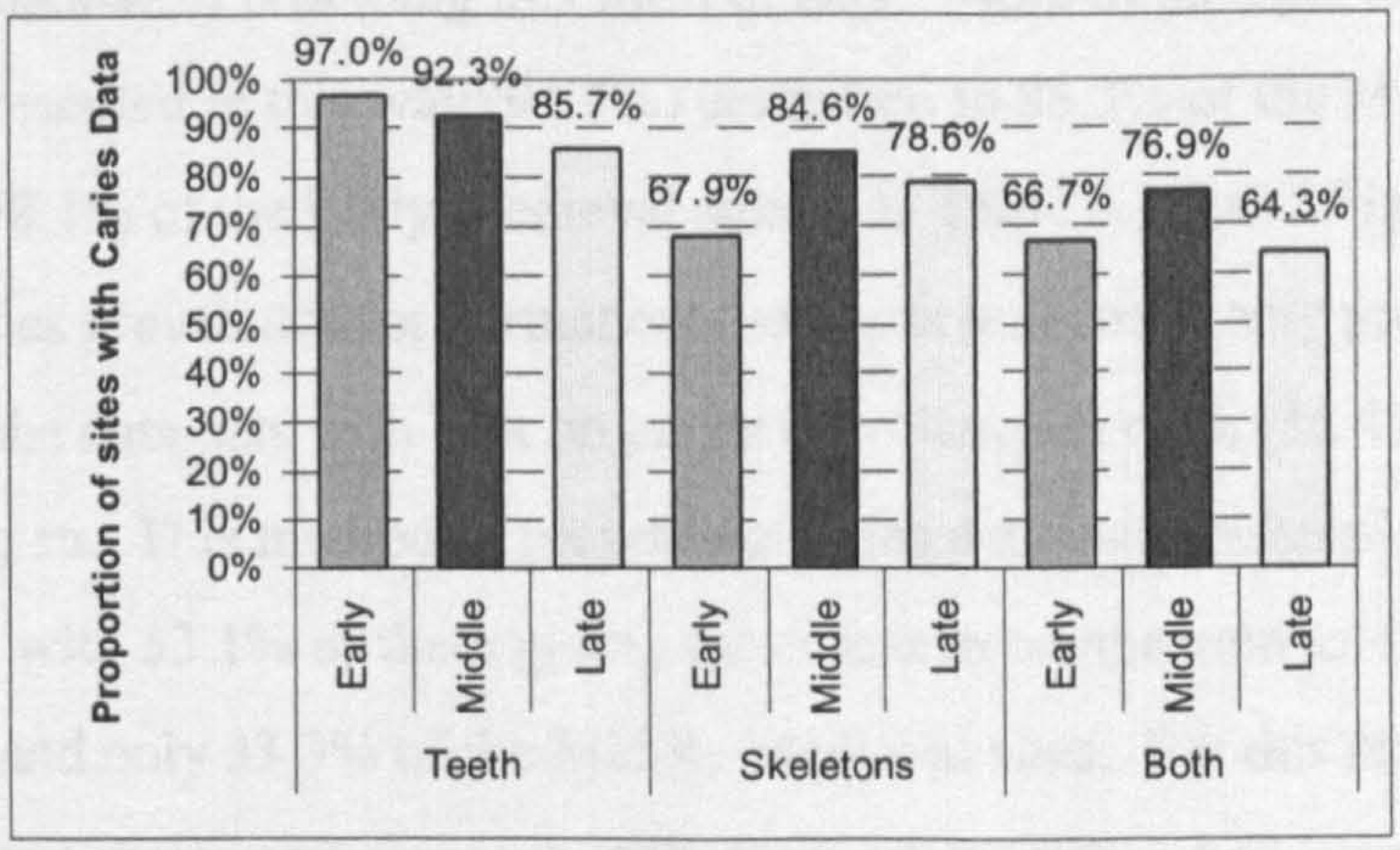


Figure 6.1:1 Data-sets presenting caries prevalence data for teeth, individuals, or both as a proportion of the data-sets with some form of caries data.

The most popular method of presenting caries data was in the form of prevalence in teeth, with 91.9% of data-sets with caries data, or 77.3% of the total sites, presenting their data in this way. In comparison, 75.7% of those with caries data (63.6% of the total sites) gave caries prevalence rates for individuals, and only 67.6% of the data-sets with caries data (56.8% of the total sites) gave caries prevalence rates for both teeth and individuals. The preference for presenting caries data as prevalence in teeth was strongest in the Early Medieval sites, with 97.0% of those with caries data providing the data in this form, compared to 67.9% providing data for caries prevalence in individuals, and weakest amongst the Late Medieval sites, with only 85.7% giving data on the caries prevalence in teeth and 78.6% giving data on the prevalence in individuals (see Table 6.1:2 and Figure 6.1:1).

Unfortunately, although 91.9% of the data-sets gave caries prevalence data for teeth, the type of data provided varied and not all gave their data in a way comparable with other sites. Prevalence data could be provided for teeth from adults, teeth from males and/or females, for permanent teeth (from adults and subadults combined), for teeth from subadults (deciduous only, permanent only, and both combined), but not all of these forms of data were provided by all data-sets. Table 6.1:3 shows the number of sites providing different data on caries prevalence in teeth.

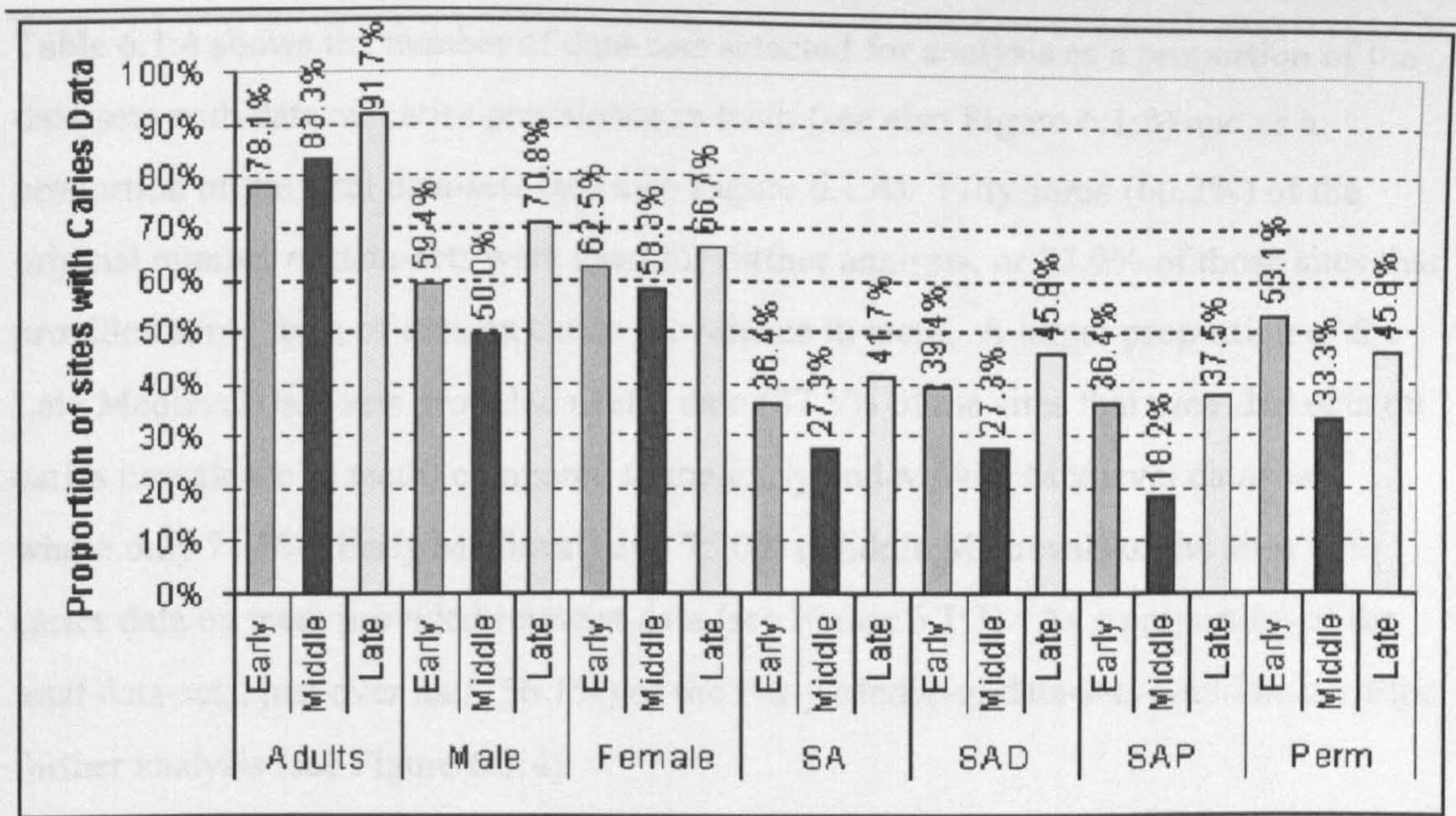
The most common form of presenting data on caries prevalence in teeth was for teeth from adults, with 83.8% of the data-sets with data on caries prevalence in teeth (or 64.8% of total data-sets) providing this form of data. More of the Late Medieval data-sets had data presented in this way (91.7%) compared to 83.3% of the Middle Medieval and 78.1% of the Early Medieval sites (see Table 6.1:3 and Figure 6.1:2). Data on the caries prevalence for permanent teeth was less commonly presented, with only 47.1% of the data-sets with data on caries prevalence in teeth (36.4% of the total data-sets) doing so. This method of presenting caries data was preferred for the Early Medieval sites, with 53.1% of them giving these data in comparison to 45.8% of the Late Medieval and only 33.3% of the Middle Medieval sites. For this reason, it was decided to analyse caries prevalence in teeth from adults rather than in permanent teeth. The two prevalence rates cannot be compared as that for permanent teeth includes some teeth from subadults, which are likely to lower the prevalence of caries. This could be seen in those data-sets where prevalence rates for both permanent teeth and teeth from adults were provided. The prevalence of caries in permanent teeth was consistently lower than that in teeth from adults. Out of 27 sites with data on both, in only one site was the caries prevalence in permanent teeth higher than that for teeth from adults, and even then the difference was only 0.19%. The difference between the two prevalence rates ranged between 0.01% and 2.61%, and the mean difference was 0.75%.

Table 6.1:3 Number of data-sets providing different data on caries prevalence in teeth.

			Medieval Period			
			Early	**Middle**	**Late**	**Total**
Number of Data-sets:		**WCDT**	32	12	24	68
		T	41	13	34	88
Number of Data-sets with Teeth From:	**Adults**		**25**	**10**	**22**	**57**
		%WCDT	78.1%	83.3%	91.7%	83.8%
		%T	61.0%	76.9%	64.7%	64.8%
	Male		**19**	**6**	**17**	**42**
		%WCDT	59.4%	50.0%	70.8%	61.8%
		%T	46.3%	46.2%	50.0%	47.7%
	Female		**20**	**7**	**16**	**43**
		%WCDT	62.5%	58.3%	66.7%	63.2%
		%T	48.8%	53.8%	47.1%	48.9%
	Subadult Deciduous + Permanent Teeth		**12**	**3**	**10**	**25**
		%WCDT	36.4%	27.3%	41.7%	36.8%
		%T	28.6%	25.0%	29.4%	28.4%
	Subadult Decidous Teeth		**13**	**3**	**11**	**27**
		%WCDT	39.4%	27.3%	45.8%	39.7%
		%T	31.0%	25.0%	32.4%	30.7%
	Subadult Permanent Teeth		**12**	**2**	**9**	**23**
		%WCDT	36.4%	18.2%	37.5%	33.8%
		%T	28.6%	16.7%	26.5%	26.1%
	Permanent Teeth (adults & subadults)		**17**	**4**	**11**	**32**
		%WCDT	53.1%	33.3%	45.8%	47.1%
		%T	41.5%	30.8%	32.4%	36.4%

WCDT = Number of data-sets with data on caries prevalence in teeth; **T** = Total no. of data-sets.

After caries prevalence in teeth from adults, the next most commonly presented prevalence data for teeth was that for adult teeth divided into teeth from males and/or females: of the data-sets with data on caries prevalence in teeth, 61.8% gave a prevalence rate for teeth from males (47.7% of the total data-sets) and 63.2% gave a prevalence rate for teeth from females (48.9% of the total data-sets; see Table 6.1:3 and Figure 6.1:2). One site only gave a prevalence rate for males, and two sites only for females, hence the slight difference between the numbers of sites with data for teeth from both sexes. The Late Medieval data-sets were more likely to provide data on caries prevalence for the teeth from both sexes (70.8% for male teeth and 66.7% for female teeth) than the Early Medieval (male teeth: 59.4%, female teeth: 62.5%) or Middle Medieval (male teeth: 50.0%, female teeth: 58.3%) data-sets.



SA = Subadults (deciduous + permanent teeth); SAD = Subadult deciduous teeth; SAP = Subadult permanent teeth; Perm = Permanent teeth (from adults and subadults).

Figure 6.1:2 The proportion of data-sets providing data on caries prevalence in different.

The amount of data on teeth from subadults was particularly disappointing (see Table 6.1:3 and Figure 6.1:2). Of the sites with data on caries prevalence in teeth, 36.8% gave data on all teeth from subadults (permanent and deciduous combined), 39.7% gave data on deciduous teeth, and 33.8% gave data on permanent teeth from subadults. As a proportion of the total data-sets, these figures are 28.4%, 30.7% and 26.1% respectively. Data on caries prevalence in subadult teeth were least likely to be obtained from the Middle Medieval sites, with only 27.3% giving data for deciduous teeth or deciduous and permanent teeth combined, and 18.2% giving data on prevalence in permanent teeth from subadults.

Based on these figures, it was decided to concentrate analysis on caries prevalence in teeth from adults, and teeth from adults divided into male and female, as these were the most commonly presented form of prevalence data available. All further analysis relates to these sites only, unless otherwise stated. All the data-sets that provided data on caries prevalence in teeth from adults are listed in Appendix 4, together with whether they provided data on teeth from males and/or females, or data on caries prevalence in individuals. A list of the final selection of sites used for further analysis is given in Appendix 5.

Table 6.1:4 shows the number of data-sets selected for analysis as a proportion of the data-sets with data on caries prevalence in teeth (see also Figure 6.1:3) and as a proportion of the total data-sets (see also Figure 6.1:4). Fifty-three (60.2%) of the original number of data-sets were used for further analysis, or 77.9% of those sites that provided some form of data on caries prevalence in teeth. A larger proportion of the Late Medieval data-sets provided useful data (87.5% of the sites that provided data on caries prevalence in teeth) compared to the Early and Middle Medieval data-sets where only 71.9% (Early Medieval) and 75.0% (Middle Medieval) of the sites with caries data on teeth provided relevant data (see Figure 6.1:3). As a proportion of the total data-sets, just over half (56.1%) of the Early Medieval data-sets could be used for further analysis (see Figure 6.1:4).

Table 6.1:4 Number of data-sets selected for analysis.

			Medieval Period			
Number of Data-sets:			**Early**	**Middle**	**Late**	**Total**
		WCDT	32	12	24	68
		T	41	13	34	88
Number of Data-sets Selected with Teeth From:	**Adults**		**23**	**9**	**21**	**53**
		%WCDT	71.9%	75.0%	87.5%	77.9%
		%T	56.1%	69.2%	61.8%	60.2%
	Male/ Female		**19**	**6**	**16**	**41**
		%Adults	82.6%	66.7%	76.2%	77.4%
		%WCDT	59.3%	50.0%	66.7%	60.5%
		%T	46.3%	46.2%	47.1%	46.6%

WCDT = Number of data-sets with data on caries prevalence in teeth; **T** = Total no. of data-sets.

Less than half the total data-sets (46.6%) gave data on caries prevalence in teeth from males and females. This figure was similar for all periods (see Figure 6.1:3 and Figure 6.1:4). Seventy-seven percent of the data-sets that gave data on caries prevalence in teeth from adults also provided data on caries prevalence in male and female teeth: this figure was 82.6% for the Early Medieval, 76.2% for the Late Medieval and 66.7% for the Middle Medieval data-sets. The Early Medieval sites were least likely to have useful data, but of those that did have data on caries prevalence in teeth from adults a higher proportion also provided data for teeth from males and females. In contrast the Middle Medieval sites were most likely to have data on caries prevalence in teeth from adults, yet a lower proportion of these would give data on teeth from males and females (see Figure 6.1:4).

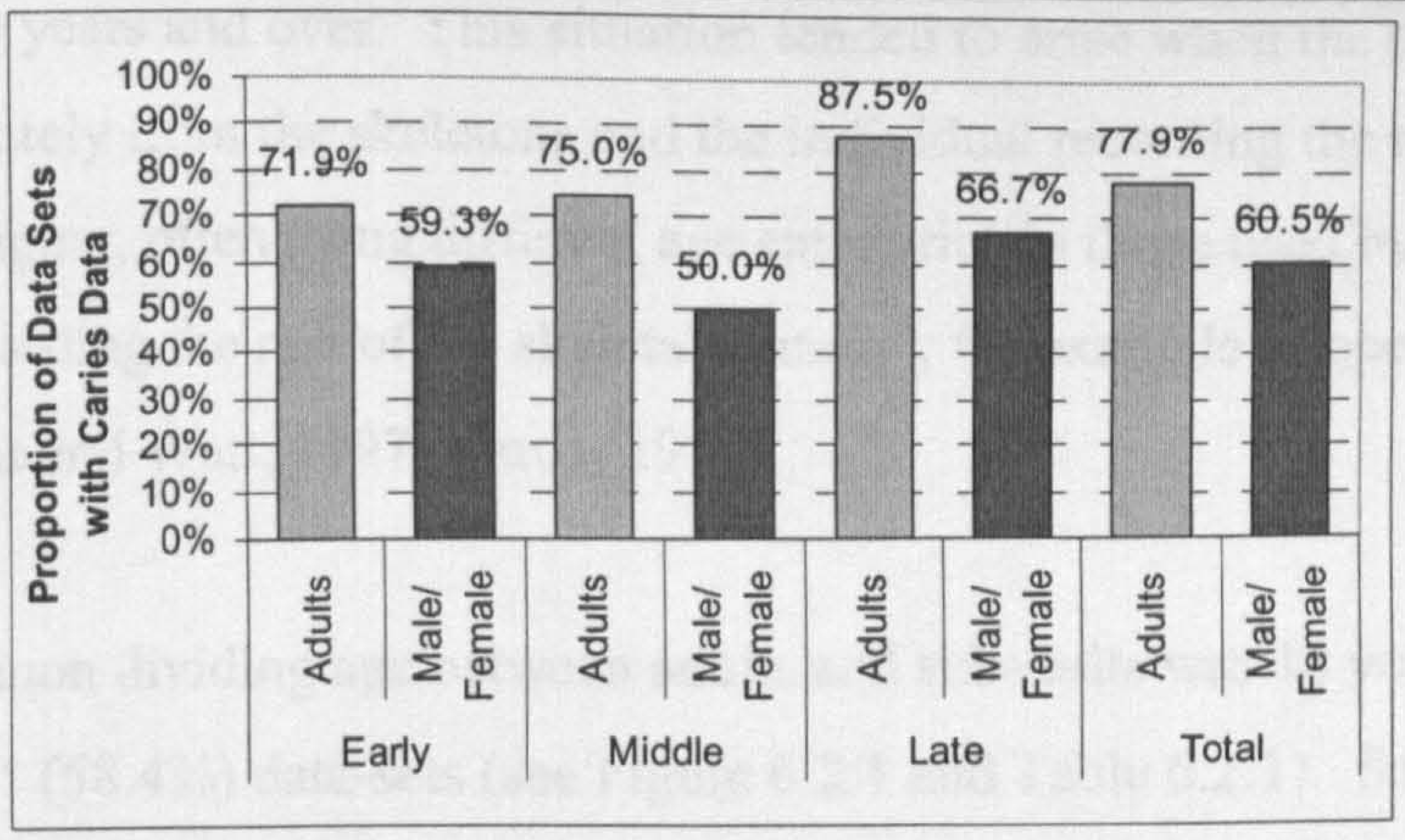


Figure 6.1:3 The selected data-sets as a proportion of data-sets with data on caries prevalence in teeth.

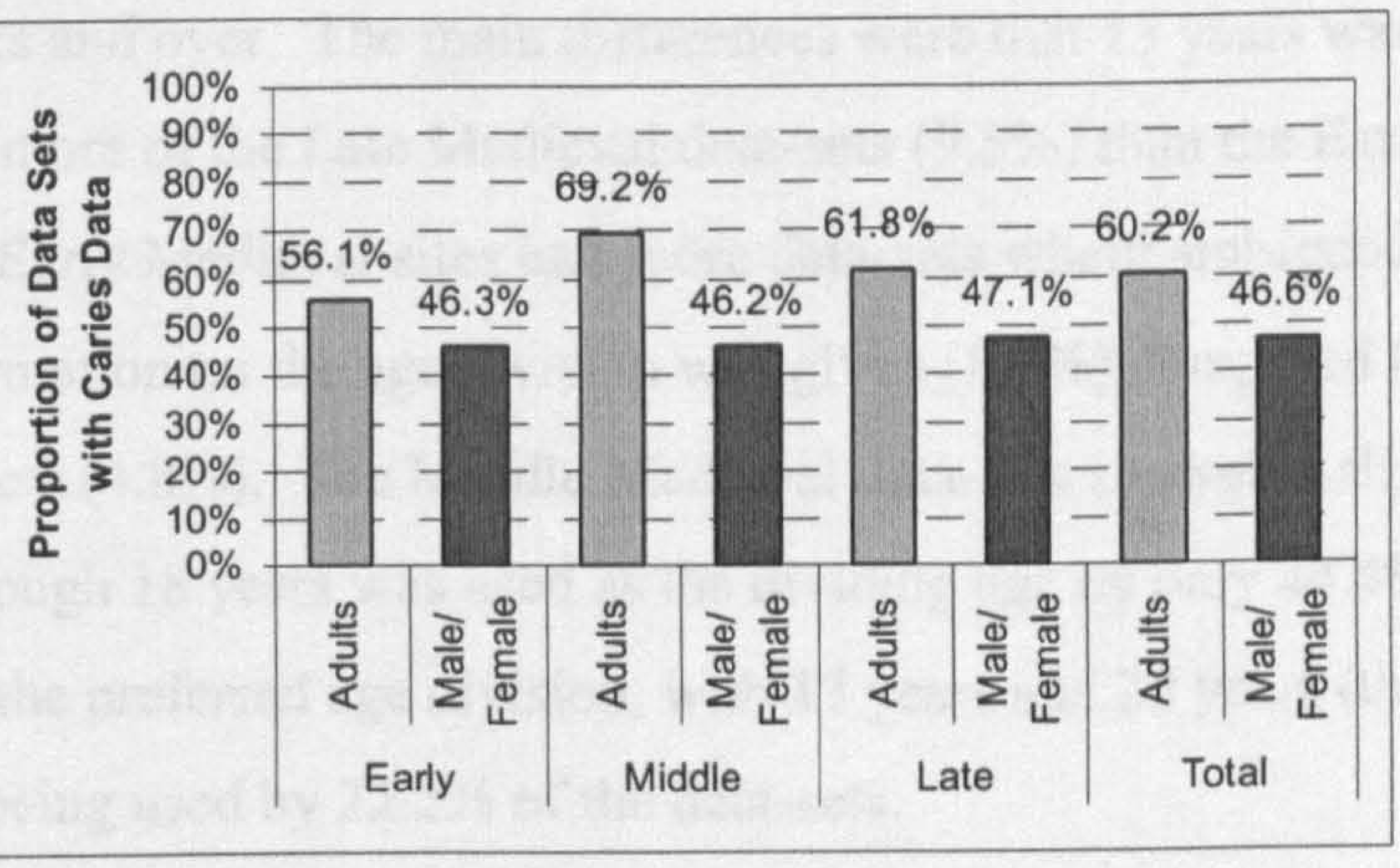


Figure 6.1:4 The selected data-sets as a proportion of total data-sets.

6.2 The Age Division Between Adults and Subadults.

Amongst the data-sets selected for further analysis, the definition of 'adult' varied from age 15 and over to age 20 and over. Usually, the age separating adults and subadults was stated in the skeletal report, but it was not in 9 out of 53 of the data-sets (17%). In these instances, and where data had been collated from the skeletal catalogue, the age division had to be decided by the author. This was done on the basis of the ages given for each skeleton in the catalogue and on the numbers of adults/subadults given in the text. Occasionally the age division was unclear, or was inconsistent between different sections of the report, with some tables or sections of the text, for example, referring to adults as 15 years and over, and others as 18 years and over, or 20 years and over. This situation tended to arise when the teeth had been analysed separately from the skeletons and the individual recording the teeth carried out their own aging, often using different age categories to those used by the osteologist recording the rest of the skeletal material, for example as occurred at Whithorn (Lunt and Watt, 1997; Cardy, 1997).

The most common dividing age between adults and subadults was 18 years, which was used for 31 (58.4%) data-sets (see Figure 6.2:1 and Table 6.2:1). Seventeen years was the next most popular age-division (13.2%), then 20 (11.3%). There was little difference between the proportions of Early and Late Medieval data-sets using the different age divisions, with around 61% of the data-sets in both periods defining adults as 18 years and over. The main differences were that 15 years was used as the age division for more of the Late Medieval data-sets (9.5%) than the Early Medieval (4.3%), and the Early Medieval sites had more data-sets where ambiguous or conflicting information on the age division was given (8.7%) compared to the Late Medieval data-sets (4.8%). The Middle Medieval data-sets showed a slightly different pattern, but although 18 years was used as the dividing age by only 44.4% of the data-sets, it was still the preferred age division, with 17 years and 20 years (the next most common) both being used by 22.2% of the data-sets.

Table 6.2:1 Number of data-sets using different age divisions between adults and subadults.

Age Division (years)	Medieval Period							
	Early		Middle		Late		All	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
15	1	4.3%	0	0.0%	2	9.5%	3	5.7%
16	1	4.3%	1	11.1%	1	4.8%	3	5.7%
17	3	13.0%	2	22.2%	2	9.5%	7	13.2%
18	14	60.9%	4	44.4%	13	61.9%	31	58.4%
20	2	8.7%	2	22.2%	2	9.5%	6	11.3%
?	2	8.7%	0	0.0%	1	4.8%	3	5.7%
Total:	23		9		21		53	

(n) = Number.

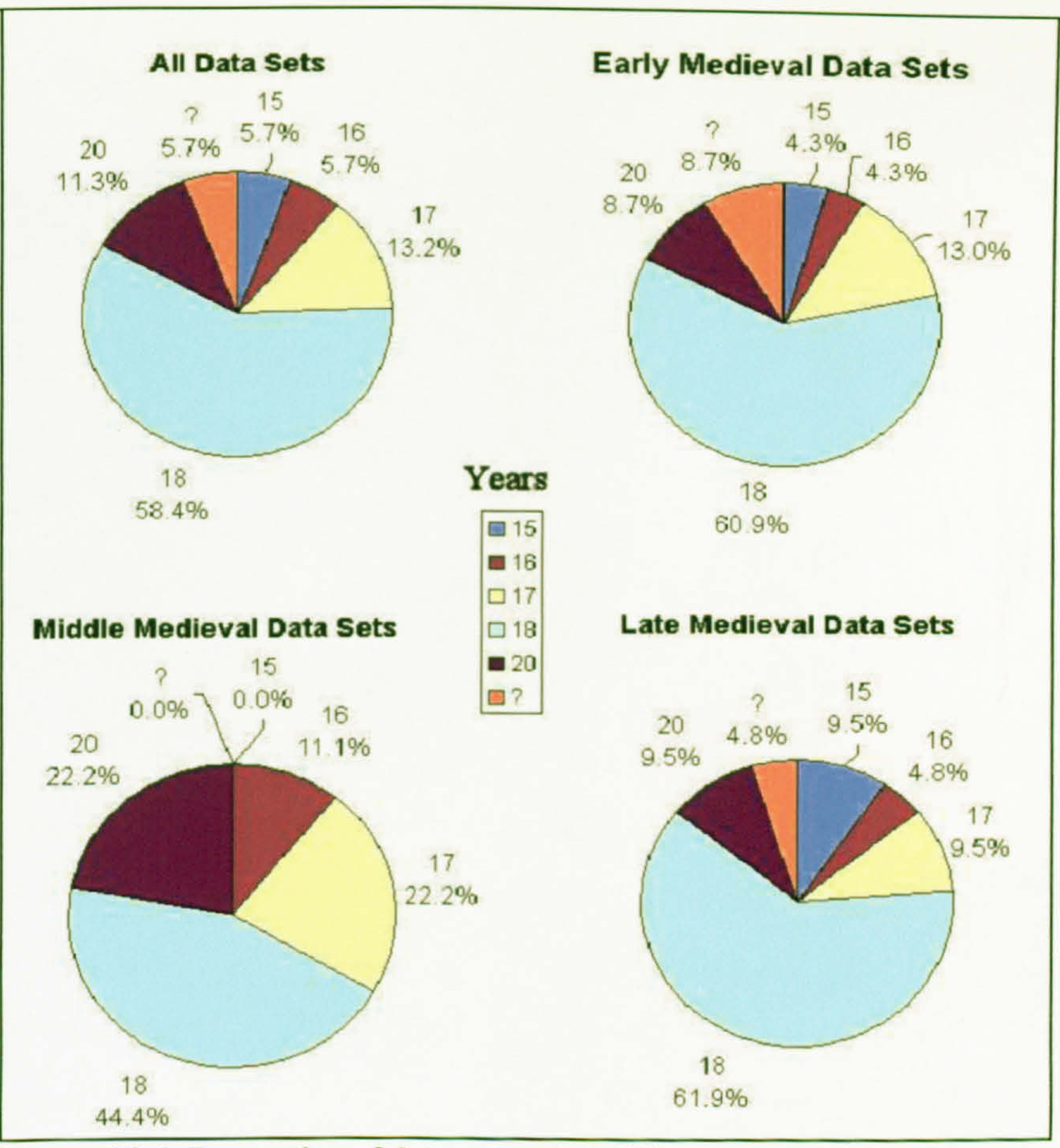


Figure 6.2:1 Proportion of data-sets using different age divisions between adults and subadults.

6.3 Chronological Division.

6.3.1 Medieval Main Periods: Early Medieval; Middle Medieval; Late Medieval.

6.3.1.1 Proportions of Adults and Subadults.

The largest sample came from the Late Medieval data-sets, numbering 5,410 skeletons in total. However, as there were no data provided on the number of adults and subadults for the 146 skeletons from the Isle of Ensay, these were excluded from the figures in Table 6.3:1, and in all subsequent tables where relevant. The smallest sample of 1,362 skeletons came from the Middle Medieval data-sets (see Table 6.3:1). Adults made up two-thirds to three-quarters of the overall sample: 70.7% of the individuals from all data-sets were adults (see Table 6.3:1). The proportion of adult and subadult individuals was similar for all three periods, although slightly fewer adults were found in the Middle Medieval data-sets (64.4%) and slightly more subadults (35.5%). The proportion of unaged individuals was low, at 0.2% overall, and was also similar across all three periods.

Table 6.3:1 Number of adult, subadult and unaged individuals in the Early, Middle and Late Medieval periods.

Medieval Period	Adult (% Total)	Subadult (% Total)	Unaged (% Total)	Total Skeletons
Early	**1739**	**745**	**11**	**2495**
	69.7%	29.9%	0.4%	-
Middle	**877**	**483**	**2**	**1362**
	64.4%	35.5%	0.1%	-
Late	**3832**	**1427**	**5**	**5264 ➊**
	72.8%	27.1%	0.1%	-
Total	**6448**	**2655**	**18**	**9121➊**
	70.7%	29.1%	0.2%	-

These data exclude - ➊ 146 skeletons from the Isle of Ensay data-set, as there were no data for numbers of adults and subadults.

6.3.1.2 Sex Distribution.

The proportions of males, females and unsexed adults were calculated for those data-sets providing data on caries prevalence in both sexes (see Table 6.3:2). The total number of adults in Table 6.3:2 differs from the totals given in Table 6.3:1 because Table 6.3:1 includes all of the selected sites, whereas Table 6.3:2 includes only those with data on caries prevalence in both sexes. Overall, there were slightly more males than females: 57.8% of the sexed adults were male and 42.2% were female. Although 50.4% of all adults were male, only 36.8% were female. Whilst it is possible that all the unsexed adults were female, in reality this is unlikely to be the case.

Table 6.3:2 Number and percentage of males, females and unsexed adults in the Early, Middle and Late Medieval periods.

Medieval Period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Early		**609**	**604**	**241**	**1213**	**1454**
	%Total Adults	41.9%	41.5%	16.6%	83.4%	-
	%Sexed Adults	50.2%	49.8%	-	-	-
Middle		**308**	**250**	**41**	**558**	**599**
	%Total Adults	51.4%	41.7%	6.8%	93.2%	-
	%Sexed Adults	55.2%	44.8%	-	-	-
Late		**1062**	**590**	**223**	**1652**	**1875**
	%Total Adults	56.6%	31.5%	11.9%	88.1%	-
	%Sexed Adults	64.3%	35.7%	-	-	-
Total		**1979**	**1444**	**505**	**3423**	**3928**
	%Total Adults	50.4%	36.8%	12.9%	87.1%	-
	%Sexed Adults	57.8%	42.2%	-	-	-

There were differences between the three main chronological periods concerning the proportion of males and females (see Table 6.3:2). The Early Medieval period had the highest number of unsexed individuals at 16.6%, but of those adults that could be sexed, half were male and half were female (50.2% and 49.8%). This distribution of males and females was not significantly different from that expected in a normal population ($X^2 = 0.0206$, $p>0.05$, d.f. = 1). However, the Late Medieval period, with the highest proportion of males at 64.3%, had significantly more males in the sample than would be expected due to chance alone ($X^2 = 134.4571$, $p<0.001$, d.f. = 1). The Middle Medieval period lies between the Early and Late Medieval periods, with 55.2% of sexed adults being male ($X^2 = 6.0287$, $p<0.025$, d.f. = 1). This was significantly different from the expected 50/50 distribution at the 2.5% level, but not at the 1% level.

The proportion of males and females in the Early Medieval data-sets was not significantly different from that in the Middle Medieval data-sets ($X^2 = 3.8130$, $p>0.05$, d.f. = 1). However, it was significantly different from that in the Late Medieval data-sets ($X^2 = 57.0422$, $p<0.001$, d.f. = 1). The proportion of males and females in the Late Medieval data-sets was also significantly different from that in the Middle Medieval data-sets ($X^2 = 14.6227$, $p<0.001$, d.f. = 1).

6.3.1.3 Age Distribution.

6.3.1.3.1 Adults in General.

The number of adults assigned to an age range have been labelled Aged Adults, as opposed to those that could not be aged any more specifically than simply 'adult', which are termed Unaged Adults. The proportion of Aged Adults was close to three-quarters of the overall sample, at 74.1%, and was similar between the Early and Late Medieval samples at 73.9% and 73.5% respectively. The Middle Medieval sample had a slightly higher proportion of Aged Adults, at 78.2% (see Table 6.3:3).

The distribution of adults within the four age categories differed significantly between the three periods (see Table 6.3:4). In the Early Medieval sample, roughly a quarter of the adults were found in each age category, with just under half the individuals in the combined two older age categories (47.2%; see Table 6.3:3 and Figure 6.3:1). In the Middle Medieval sample, the proportion of individuals in the first three categories (YA, YMA and OMA) was similar (27.1%, 28.4% and 28.6%), but with a smaller proportion of individuals in the oldest category (15.9%). The proportion of individuals in the older age categories was therefore lower than the Early Medieval sample, at 44.5%. In comparison, the Late Medieval sample had a large percentage of individuals in both the YMA and OMA categories (31.6% and 28.5%), with 22.0% in the oldest category, and only 17.9% in the youngest category. Half the individuals were found in the combined oldest categories (50.5%), a larger proportion than both Early and Middle Medieval samples. Therefore, the Late Medieval sample had the smallest proportion of individuals in the YA category, and the Middle Medieval had the largest. The Middle Medieval sample had the smallest proportion of adults in the OA category with the Early Medieval sample having the largest.

Table 6.3:3 Number and percentage of adults in different age categories in the Early, Middle and Late Medieval periods.

Medieval Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early	329	349	290	317	1285	454	1739
	25.6%	27.2%	22.6%	24.7%	73.9%	26.1%	
	678		607				100%
	52.8%		47.2%				
Middle	143	150	151	84	528	147	675
	27.1%	28.4%	28.6%	15.9%	78.2%	21.8%	❶
	293		235				100%
	55.5%		44.5%				
Late	501	886	800	617	2804	1012	3816
	17.9%	31.6%	28.5%	22.0%	73.5%	26.5%	❷
	1387		1417				100%
	49.5%		50.5%				
Total	973	1385	1241	1018	4617	1613	6230
	21.1%	30.0%	26.9%	22.0%	74.1%	25.9%	❶ ❷
	2358		2259				100%
	51.1%		48.9%				

These data exclude - ❶ 202 adults from Trowbridge, as they are only placed in two broad categories; ❷ 78 adults from Whithorn B and 84 of the 146 skeletons from the Isle of Ensay, for which there were no data on age.

Table 6.3:4 Results of Kolmogorov-Smirnov tests comparing adult age distributions between the Early, Middle and Late Medieval periods.

Medieval Periods Compared	Maximum Observed Difference	Dmax Significance Level		Significant ?
Early / Late	-0.0774	Dmax 0.001	0.0657	Yes
Early / Middle	0.0876	Dmax 0.01	0.0843	Yes
Middle / Late	-0.0922	Dmax 0.005	0.0821	Yes

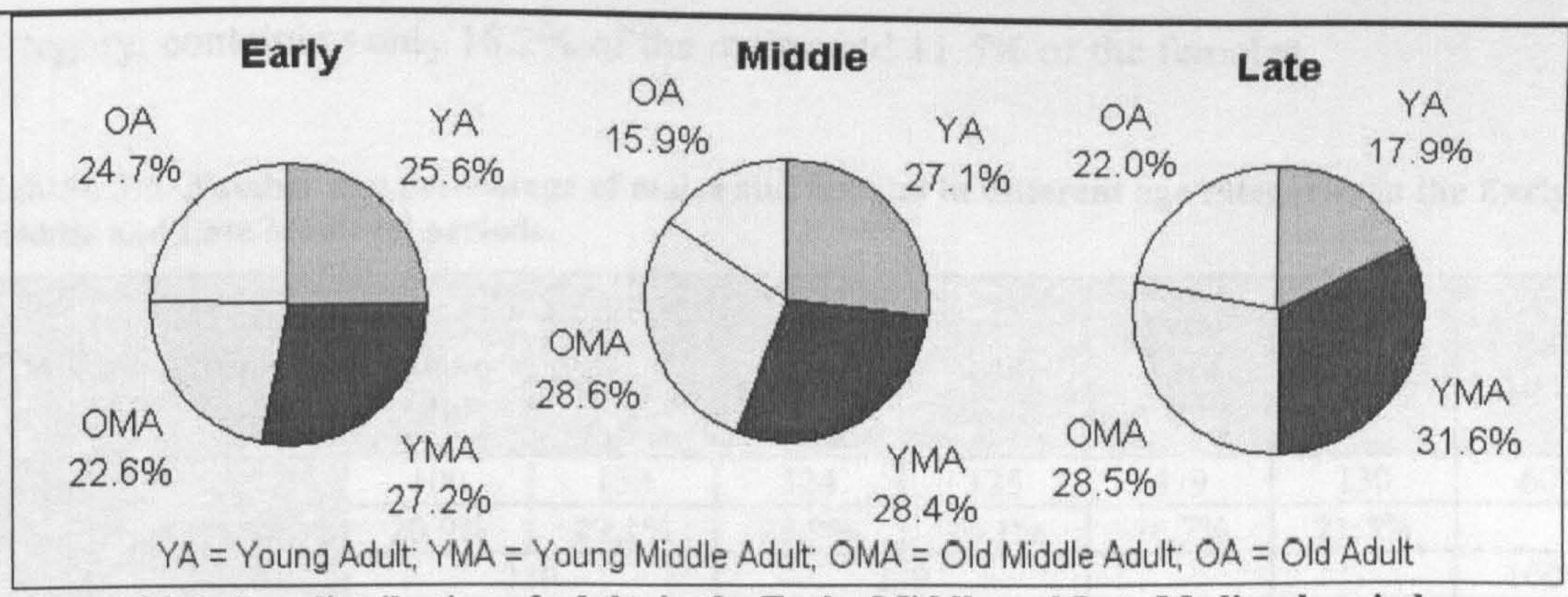


Figure 6.3:1 Age distribution of adults in the Early, Middle and Late Medieval periods.

6.3.1.3.2 Adults: Male and Female Subdivisions.

The proportions of individuals in each age category were also calculated for males and females, but only for those data-sets that provided data on caries prevalence in male and female teeth (see Table 6.3:5). For this reason, the total number of adults will differ from those in the previous section. As no details were given for the age distribution within each sex for the 93 males and 52 females from Blackfriars, Carlisle, these cannot be included in Table 6.3:5 (and subsequent tables where relevant). For this reason the total number of individuals in both sexes for the Late Medieval period differs from those shown in Table 6.3:2.

The proportion of Aged Adults for both sexes tended to be similar within each period: the largest difference of 3.8% was seen in both the Early and Middle Medieval periods, with the smallest difference (1.4%) occurring in the Late Medieval sample (see Table 6.3:5). The Late Medieval sample had the largest proportion of Aged Adults for both males (85.4%) and females (86.8%). The proportion of Aged Adults in each period, for both sexes, was higher than for the Aged Adults in general (compare Table 6.3:5 with Table 6.3:3).

The Early Medieval males had slightly more individuals in the two older age categories (52.0%) than the females (48.8%); there were also a higher percentage of females (26.1%) in the YA group than males (20.9%; see Table 6.3:5 and Figure 6.3:2). The Middle Medieval sample also had a larger proportion of males in the two older age categories (47.7%) than did the females (39.5%), and again, a higher proportion of females were seen in the YA group– 31.0% compared to 25.6% for males. For both sexes, the age group with the fewest individuals was the OA category: containing only 18.2% of the males and 11.5% of the females.

Table 6.3:5 Number and percentage of males and females in different age categories in the Early, Middle and Late Medieval periods.

Medieval Periods		Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Early	Male	100	130	124	125	479	130	609
		20.9%	27.1%	25.9%	26.1%	78.7%	21.3%	
		230		249				100%
		48.0%		52.0%				
	Female	130	125	108	135	498	106	604
		26.1%	25.1%	21.7%	27.1%	82.5%	17.5%	
		255		243				100%
		51.2%		48.8%				
Middle	Male	66	69	76	47	258	50	308
		25.6%	26.7%	29.5%	18.2%	83.8%	16.2%	
		135		123				100%
		52.3%		47.7%				
	Female	62	59	56	23	200	50	250
		31.0%	29.5%	28.0%	11.5%	80.0%	20.0%	
		121		79				100%
		60.5%		39.5%				
Late	Male	167	211	224	226	828	141	969
		20.2%	25.5%	27.1%	27.3%	85.4%	14.6%	❶
		378		450				100%
		45.7%		54.3%				
	Female	79	141	111	136	467	71	538
		16.9%	30.2%	23.8%	29.1%	86.8%	13.2%	❷
		220		247				100%
		47.1%		52.9%				
Totals	Male	333	410	424	398	1565	321	1886
		21.3%	26.2%	27.1%	25.4%	83.0%	17.0%	❶
		743		822				100%
		47.5%		52.5%				
	Female	271	325	275	294	1165	227	1392
		23.3%	27.9%	23.6%	25.2%	83.7%	16.3%	❷
		596		569				100%
		51.2%		48.8%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and. ❷ 52 females from Blackfriars, Carlisle, as details of age distribution were not provided.

The age distribution in the Late Medieval sample was similar for both sexes: the proportion of individuals in the two older age groups was 54.3% for males and 52.9% for females, although the females had a slightly higher percentage in the OA group (29.1%), and a slightly lower percentage in the YA group (16.9%), than did the males (27.3% and 20.2% respectively). For all periods these differences between the male and female age distributions were not found to be significant (see Table 6.3:6).

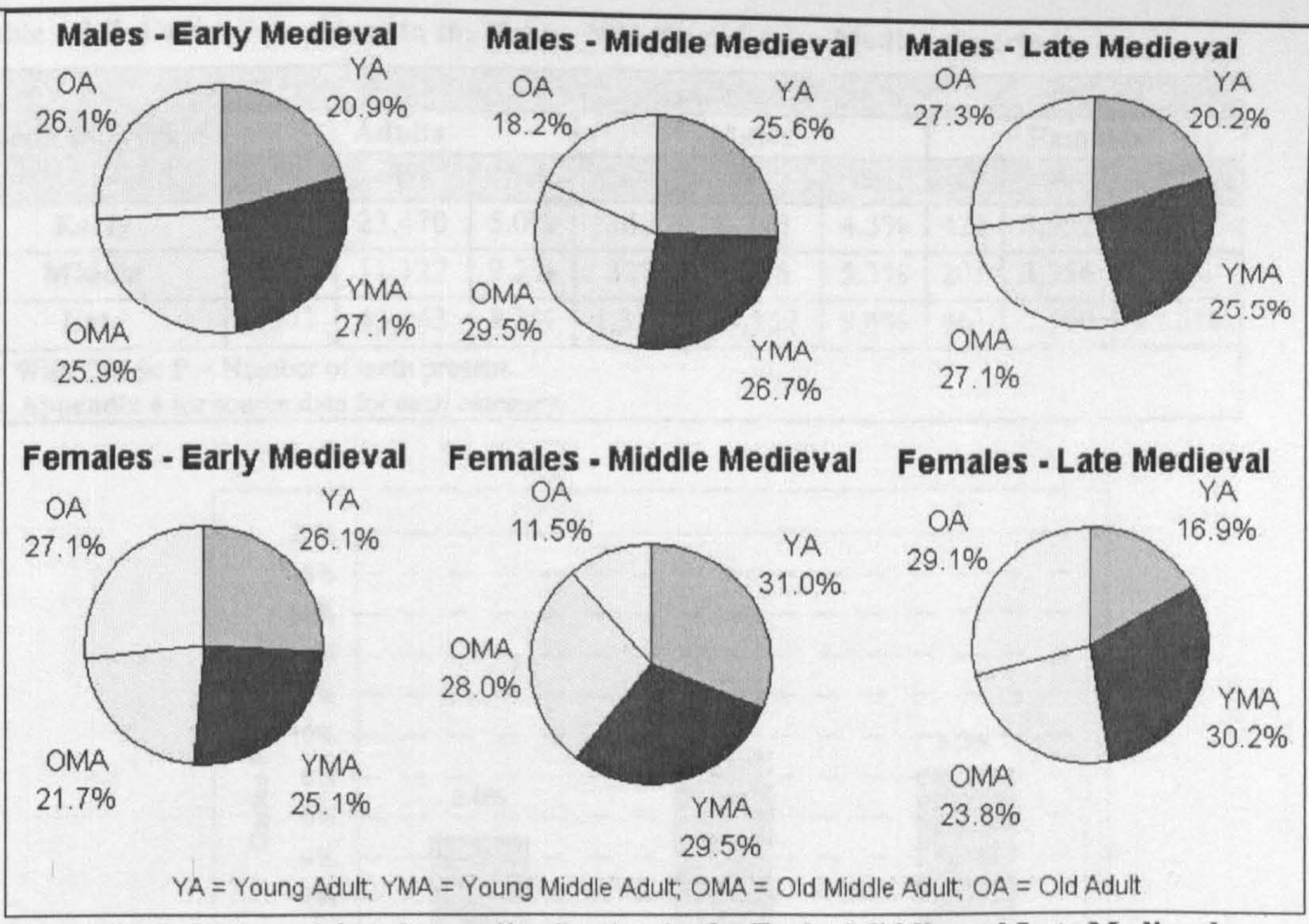


Figure 6.3:2 Male and female age distribution in the Early, Middle and Late Medieval periods.

Table 6.3:6 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within the Early, Middle and Late Medieval periods.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early Medieval	-0.0523	Dmax 0.05	0.0870	No
Middle Medieval	-0.0817	Dmax 0.05	0.1281	No
Late Medieval	0.0325	Dmax 0.05	0.0787	No

6.3.1.4 Caries Prevalence.

6.3.1.4.1 Teeth from Adults.

The overall caries prevalence in teeth from adult individuals for each of the three main periods was calculated, and the results are displayed in Table 6.3:7 and Figure 6.3:3. This table shows the number of teeth present and teeth with caries, together with the prevalence rate (teeth with caries divided by total teeth present) for each period. The Early Medieval period had the lowest caries prevalence at 5.0%. This was significantly different from the caries prevalence in the Middle Medieval period, which was nearly double this at 9.2% ($X^2 = 221.8702$, $p<0.001$, d.f. = 1), and from that in the Late Medieval period (8.3%, $X^2 = 251.9957$, $p<0.001$, d.f. = 1). The caries prevalence in the Late Medieval period was also significantly different from that in the Middle Medieval period ($X^2 = 8.4304$, $p<0.005$, d.f. = 1).

Table 6.3:7 Caries Prevalence in the Early, Middle and Late Medieval periods.

Medieval Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Early	1,172	23,470	5.0%	389	8,740	4.5%	426	8,952	4.8%
Middle	1,020	11,122	9.2%	227	4,315	5.3%	205	3,356	6.1%
Late	3,577	43,043	8.3%	1,357	14,162	9.6%	861	7,509	11.5%

C = With Caries; **P** = Number of teeth present.
See **Appendix 6** for source data for each category.

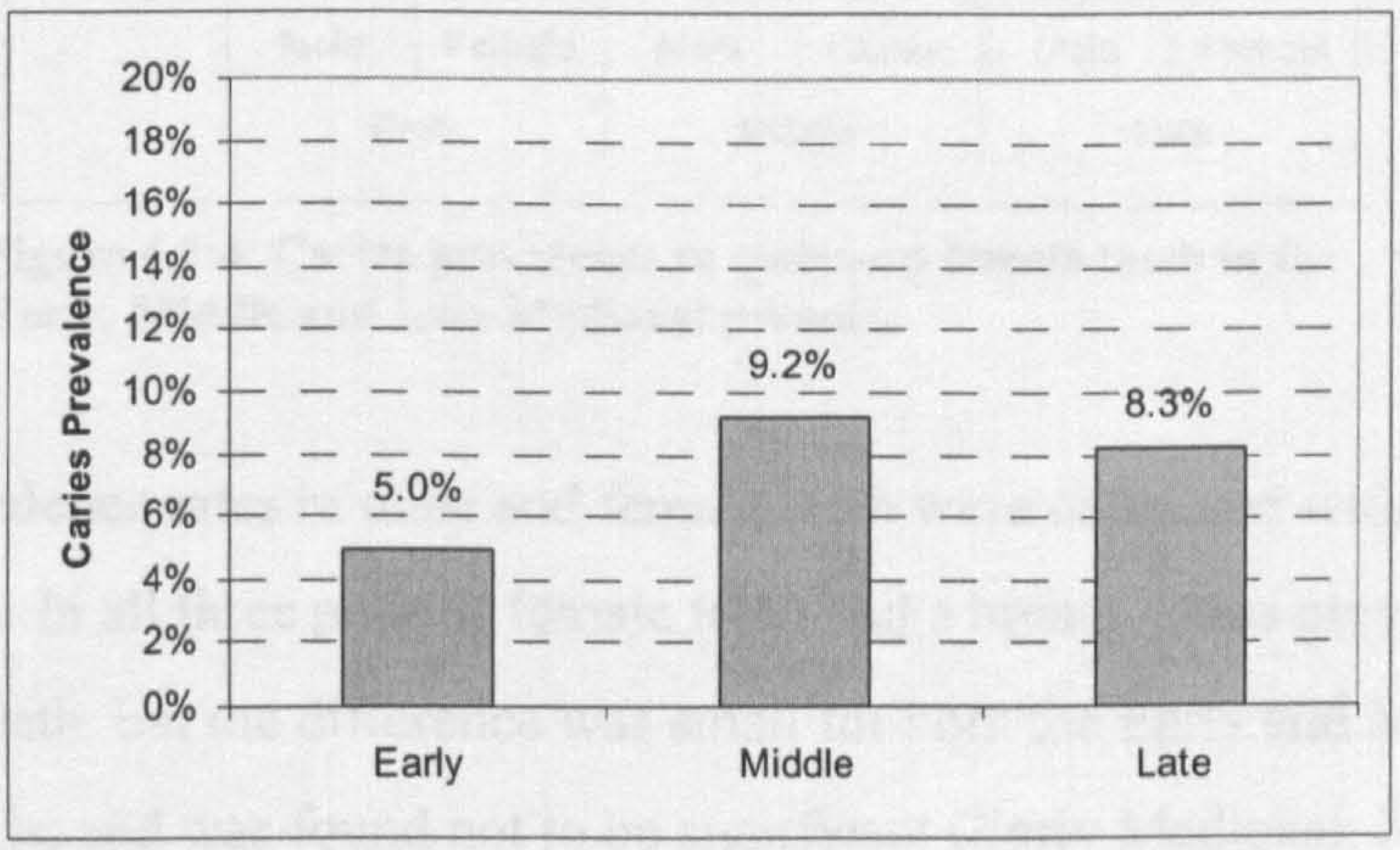


Figure 6.3:3 Caries prevalence in adult teeth in the Early, Middle and Late Medieval periods.

6.3.1.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rates for teeth from males and teeth from females were calculated for each period (shown in Table 6.3:7). As with the prevalence rate for adult teeth (described above), the lowest prevalence rates for both male and female teeth were seen in the Early Medieval period (4.5% and 4.8% respectively). However, in contrast to the adult teeth overall the highest prevalence rates occur in the Late Medieval period and not the Middle Medieval period (See Figure 6.3:4). The caries prevalence rates in both the male and female teeth were significantly different between each period (see Table 6.3:8).

Table 6.3:8 Comparison of caries prevalence in male and female teeth between pairs of periods - Early, Middle and Late Medieval periods: chi-square values and significance level.

Medieval Periods Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Early	Middle	4.2149	1	$p<0.05$	9.1427	1	$p<0.005$
Early	Late	202.0533	1	$p<0.001$	254.9204	1	$p<0.001$
Middle	Late	78.7945	1	$p<0.001$	75.2427	1	$p<0.001$

d.f. = degrees of freedom.

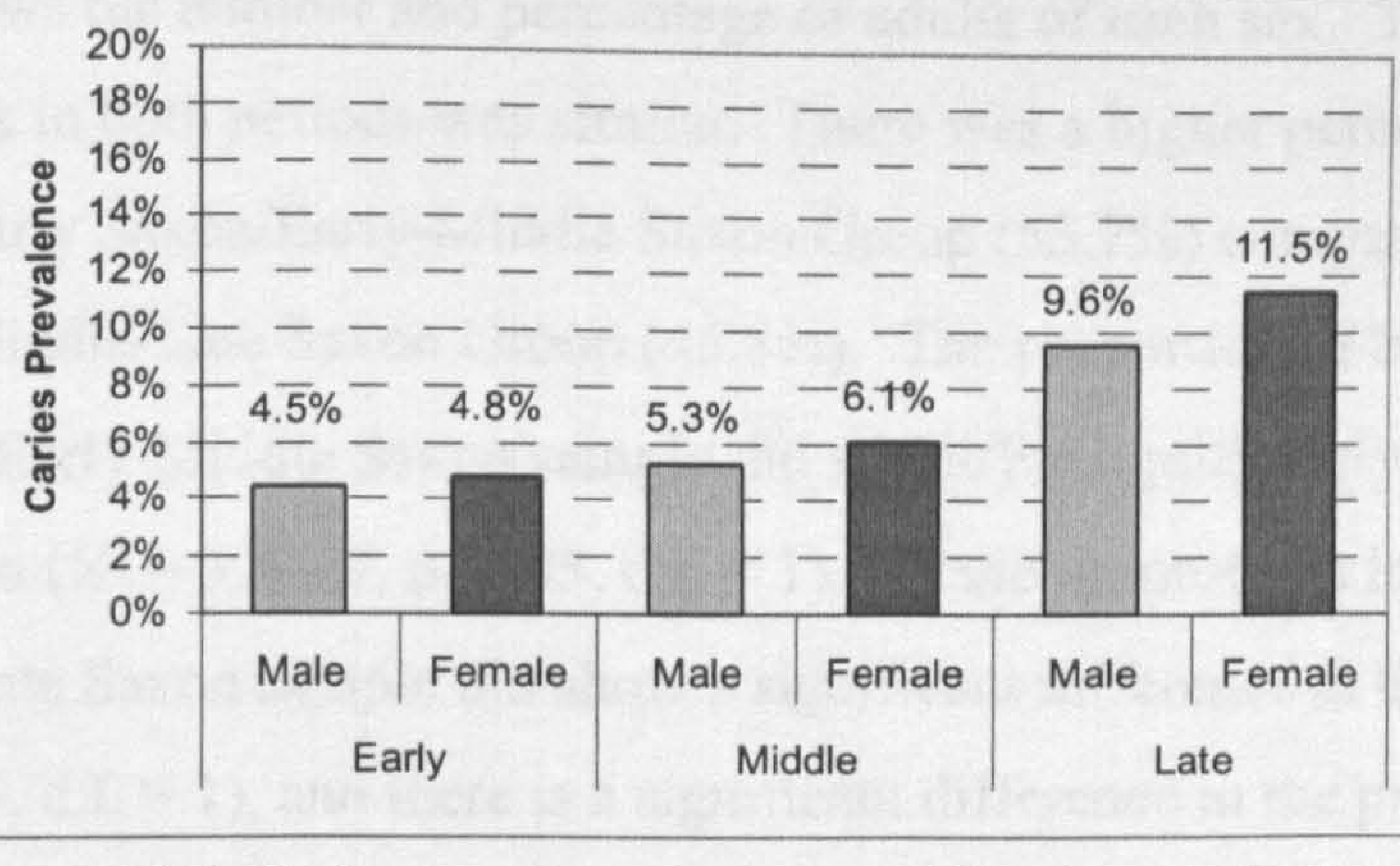


Figure 6.3:4 Caries prevalence in male and female teeth in the Early, Middle and Late Medieval periods.

The caries prevalence rates in male and female teeth were compared with each other for each period. In all three periods female teeth had a higher caries prevalence rate than the male teeth, but the difference was small for both the Early and Middle Medieval periods, and was found not to be significant (Early Medieval: $X^2 = 0.9541$, $p>0.05$, d.f. = 1; Middle Medieval: $X^2 = 2.5528$, $p>0.05$, d.f. = 1). It was only in the Late Medieval period that the difference in caries prevalence between male and female teeth was significant ($X^2 = 18.9635$, $p<0.001$, d.f. = 1).

6.3.2 Early Medieval Group Sub-Periods: Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon.

6.3.2.1 Proportions of Adults and Subadults.

The number of individuals in both Group Sub-Periods was similar, and in both cases the adults made up around 70% of the sample and the subadults 30% (see Table 6.3:9). All unaged individuals were found in the Early Saxon/Early-Middle Saxon Group Sub-Period.

Table 6.3:9 Number of adult, subadult and unaged individuals in the Early Saxon/ Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Early Medieval Group Sub-Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Early Saxon/ Early-Middle Saxon		942	418	11	1371
	%Total	68.7%	30.5%	0.8%	-
Middle Saxon/ Middle-Late Saxon		797	327	0	1124
	%Total	70.9%	29.1%	0.0%	-

6.3.2.2 Sex Distribution.

Table 6.3:10 shows the number and percentage of adults of each sex. The proportion of unsexed adults in both periods was similar. There was a higher percentage of females in the Early Saxon/Early-Middle Saxon Group (53.7%) compared to the Middle Saxon/Middle-Late Saxon Group (45.8%). The proportion of both sexes in the Early Saxon/Early-Middle Saxon sample did not differ significantly from a normal 50-50 distribution ($X^2 = 3.2927$, $p>0.05$, d.f. = 1), but the proportions in the Middle Saxon/Middle-Late Saxon sample did show a significant difference at the 5% level ($X^2 = 4.1806$, $p<0.05$, d.f. = 1), and there is a significant difference in the proportions of males and females between the two periods ($X^2 = 7.4528$, $p<0.01$, d.f. = 1).

Table 6.3:10 Number and percentage of males, females and unsexed adults in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Early Medieval Group Sub-Period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Early Saxon/ Early-Middle Saxon		**285**	**330**	**111**	**615**	**726**
	%Total Adults	39.3%	45.5%	15.3%	87.7%	-
	%Sexed Adults	46.3%	53.7%	-	-	-
Middle Saxon/ Middle-Late Saxon		**324**	**274**	**130**	**598**	**728**
	%Total Adults	44.5%	37.6%	17.9%	82.1%	-
	%Sexed Adults	54.2%	45.8%	-	-	-

6.3.2.3 Age Distribution.

6.3.2.3.1 Adults in General.

The Early Saxon/Early-Middle Saxon sample had considerably more Aged Adults compared to the Middle Saxon/Middle-Late Saxon sample (80.6% and 66.0% of the total Adults respectively; see Table 6.3:11), and the distribution of adults within the four age categories differed significantly between the two Group Sub-Periods ($D_{MAX\,obs} = 0.1466$, $D_{MAX\ 0.001} = 0.1106$). In the Early Saxon/Early-Middle Saxon sample, a large proportion of the adults were found in two younger age groups (58.8% combined), with 20.7% and 20.6% of the adults in the OMA and OA categories (41.2% combined). In contrast, the majority of the adults in the Middle Saxon/Middle-Late Saxon sample were in the older age categories, with only 44.1% of the individuals in the youngest two age categories (see Table 6.3:11 and Figure 6.3:5).

Table 6.3:11 Number and percentage of adults in different age categories in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Early Medieval Group Sub-Period	Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Early Saxon/ Early-Middle Saxon	222	224	157	156	759	183	942
	29.2%	29.5%	20.7%	20.6%	80.6%	19.4%	
	446		313				100%
	58.8%		41.2%				
Middle Saxon/ Middle-Late Saxon	107	125	133	161	526	271	797
	20.3%	23.8%	25.3%	30.6%	66.0%	34.0%	·
	232		294				100%
	44.1%		55.9%				
Total	329	349	290	317	1285	454	1739
	25.6%	27.2%	22.6%	24.7%	73.9%	26.1%	·
	678		607				100%
	52.8%		47.2%				

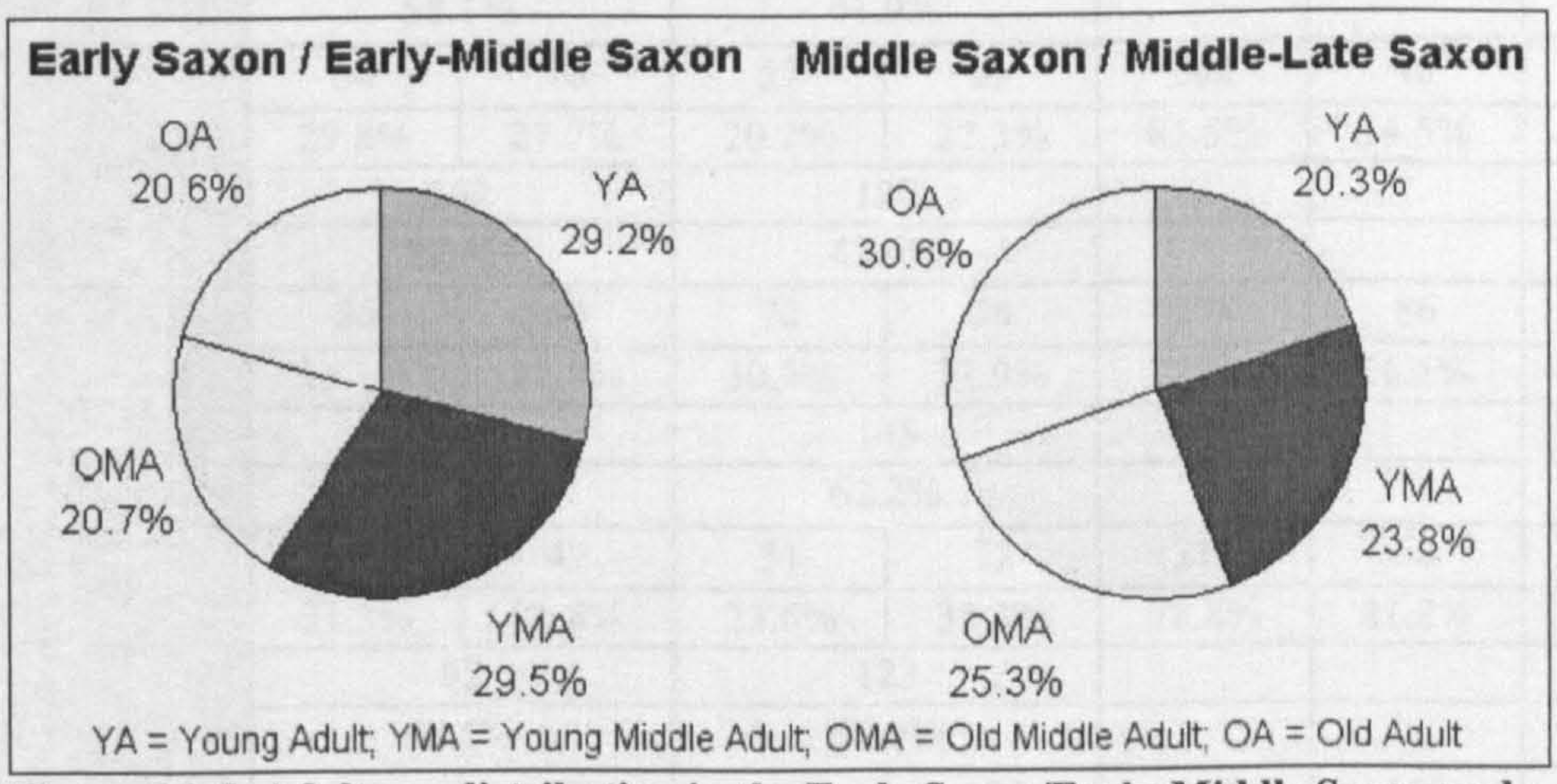


Figure 6.3:5 Adult age distribution in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

6.3.2.3.2 Adults: Male and Female Subdivisions.

The proportion of Aged Adults of both sexes was higher than the proportion of Aged Adults in general (compare Table 6.3:12 with Table 6.3:11). The Early Saxon/Early-Middle Saxon sample had a higher percentage of aged males and females than the Middle Saxon/Middle-Late Saxon sample. For both Group Sub-Periods, a higher proportion of females had been aged compared to the males (see Table 6.3:12).

In the Early Saxon/Early-Middle Saxon sample, there were larger percentages of both males and females in the two younger age groups (Male = 58.1%, Female = 57.4%), with similar proportions of each sex in each age category. In contrast, in the Middle Saxon/Middle-Late Saxon sample, there were large proportions of males and females in the two older age groups (Male = 62.2%, Female = 56.9%), with a low percentage of males in the YA category (15.1%) compared to females (21.3%; see Table 6.3:12 and Figure 6.3:6). There were no significant differences in terms of age distribution between the sexes for either Group Sub-Period (see Table 6.3:13).

Table 6.3:12 Number and percentage of males and females in different age categories in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Early Medieval Group Sub-Period		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early Saxon/ Early-Middle Saxon	Male	64	76	52	49	241	44	285
		26.6%	31.5%	21.6%	20.3%	84.6%	15.4%	
		140		101				100%
		58.1%		41.9%				
	Female	84	78	57	63	282	48	330
		29.8%	27.7%	20.2%	22.3%	85.5%	14.5%	
		162		120				100%
		57.4%		42.6%				
Middle Saxon/ Middle-Late Saxon	Male	36	54	72	76	238	86	324
		15.1%	22.7%	30.3%	31.9%	73.5%	26.5%	
		90		148				100%
		37.8%		62.2%				
	Female	46	47	51	72	216	58	274
		21.3%	21.8%	23.6%	33.3%	78.8%	21.2%	
		93		123				100%
		43.1%		56.9%				
Totals	Male	100	130	124	125	479	130	609
		20.9%	27.1%	25.9%	26.1%	78.7%	21.3%	
		230		249				100%
		48.0%		52.0%				
	Female	130	125	108	135	498	106	604
		26.1%	25.1%	21.7%	27.1%	82.5%	17.5%	
		255		243				100%
		51.2%		48.8%				

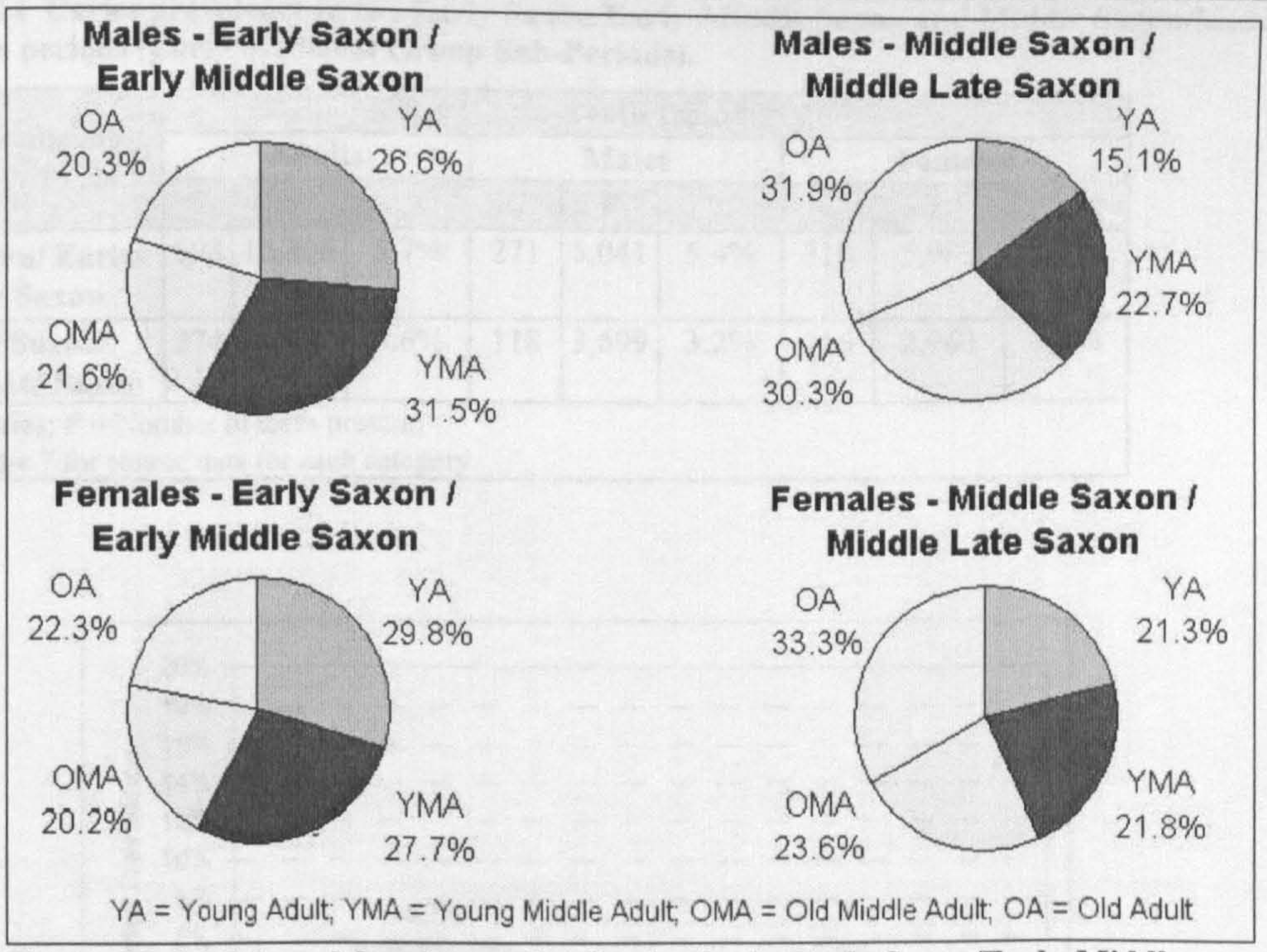


Figure 6.3:6 Male and female age distribution in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Table 6.3:13 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early Saxon/ Early-Middle Saxon	-0.0323	Dmax 0.05	0.1193	No
Middle Saxon/ Middle-Late Saxon	-0.0617	Dmax 0.05	0.1278	No

6.3.2.4 Caries Prevalence.

6.3.2.4.1 Teeth from Adults.

The Early Saxon/Early-Middle Saxon sample had a higher caries prevalence rate (5.7%) than the Middle Saxon/Middle-Late Saxon sample (3.6%; see Table 6.3:14 and Figure 6.3:7). This difference was significant at the 0.1% level ($X^2 = 48.2624$, $p<0.001$, d.f. = 1).

Table 6.3:14 Caries prevalence in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

Early Medieval Group Sub-Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Early Saxon/ Early-Middle Saxon	898	15,806	5.7%	271	5,041	5.4%	310	5,989	5.2%
Middle Saxon/ Middle-Late Saxon	274	7,664	3.6%	118	3,699	3.2%	116	2,963	3.9%

C = With Caries; **P** = Number of teeth present;
See **Appendix 7** for source data for each category.

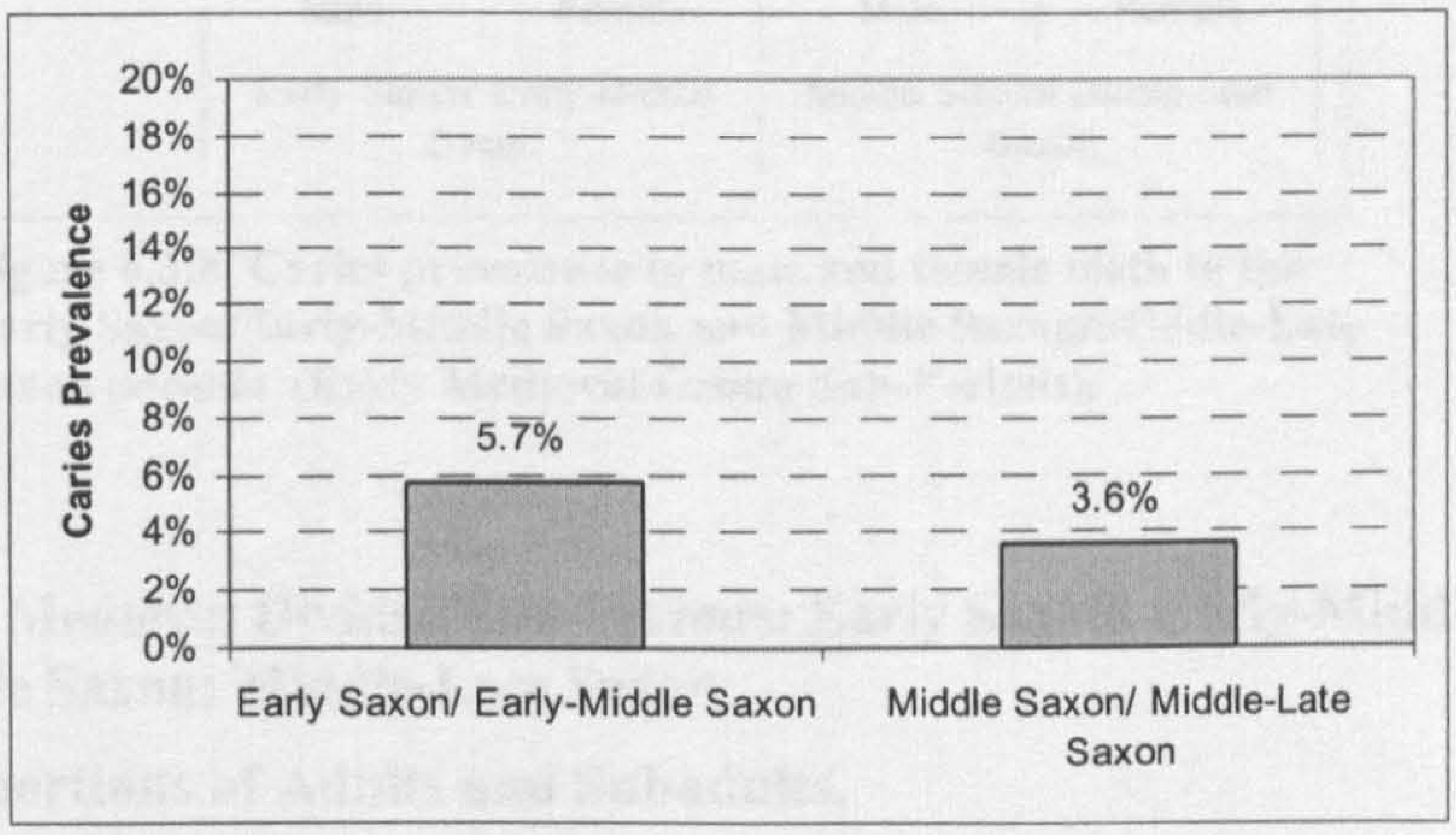


Figure 6.3:7 Caries prevalence in adult teeth in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

6.3.2.4.2 Teeth from Adult Male and Female Subdivisions.

As with the adult teeth, the caries prevalence rate in both male and female teeth was higher in the Early Saxon/Early-Middle Saxon sample than in the Middle Saxon/Middle-Late Saxon sample (see Table 6.3:14 and Figure 6.3:8), and these differences between the Sub-Periods were significant for teeth of both sexes (Male: $X^2 = 23.9702$, $p<0.001$, d.f. = 1; Female: $X^2 = 6.9570$, $p<0.01$, d.f. = 1).

The caries prevalence rates for the male and female teeth were similar within each Sub-Period. The difference was negligible in the Early Saxon/Early-Middle Saxon sample, with the male teeth having a prevalence of 5.4% and female teeth a prevalence of 5.2%. This difference was not significant ($X^2 = 0.2189$, $p>0.05$, d.f. = 1). In the Middle Saxon/Middle-Late Saxon sample, the female teeth had a slightly higher prevalence (3.9%) than the male teeth (3.2%), but again this was not statistically significant ($X^2 = 2.5508$, $p>0.05$, d.f. = 1).

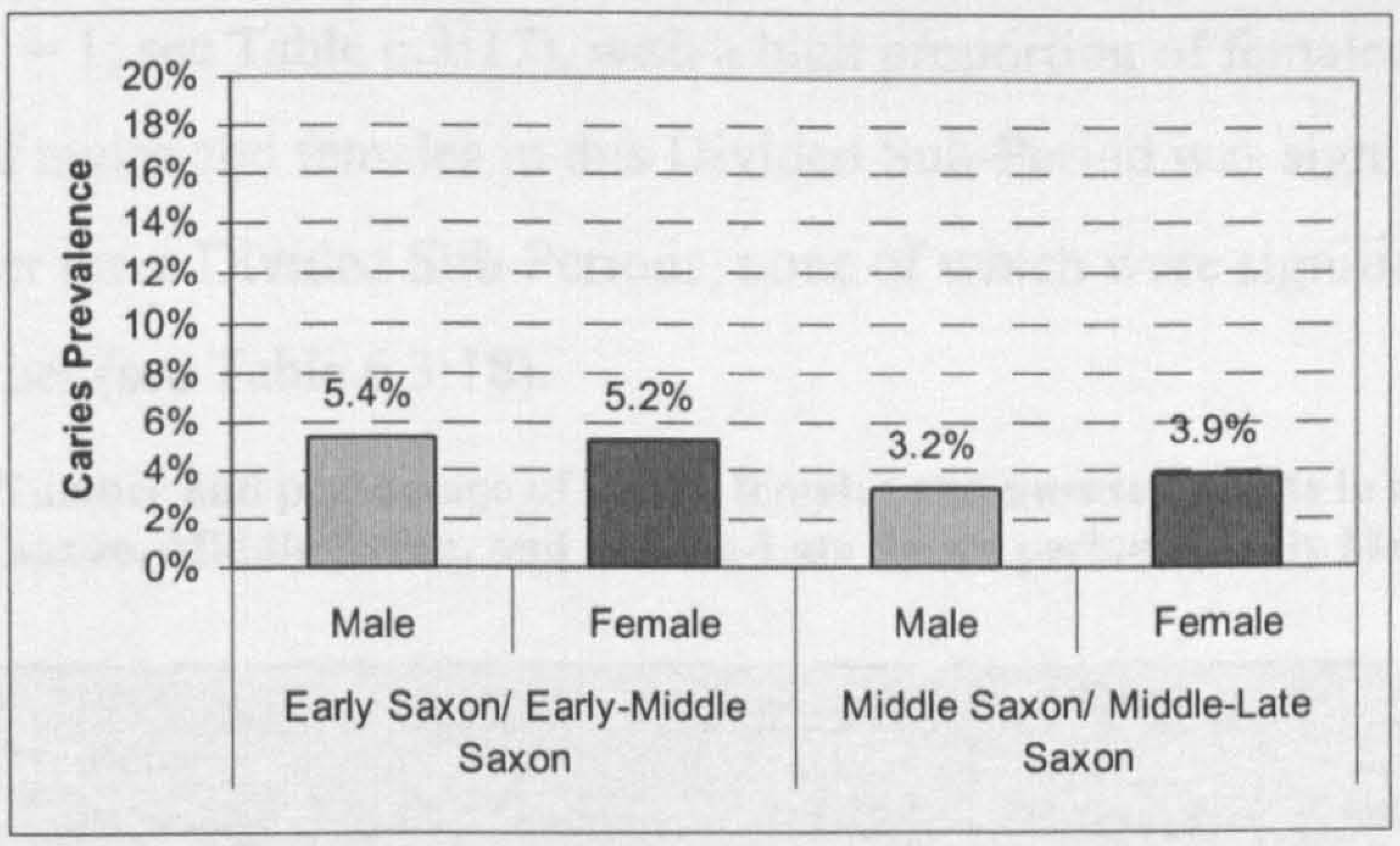


Figure 6.3:8 Caries prevalence in male and female teeth in the Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon periods (Early Medieval Group Sub-Periods).

6.3.3 Early Medieval Divided Sub-Periods: Early Saxon; Early-Middle Saxon; Middle Saxon; Middle-Late Saxon.

6.3.3.1 Proportions of Adults and Subadults.

The smallest sample came from the Middle Saxon Divided Sub-Period (482 skeletons), and the largest from the Early-Middle Saxon Divided Sub-Period (755 skeletons; see Table 6.3:15). Again most Divided Sub-Periods had c. 70% adults to 30% subadults, although the Early Saxon Divided Sub-Period had fewer adults (66.6%). This period also had the most unaged individuals (9, 1.5%).

Table 6.3:15 Number of adult, subadult and unaged individuals in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Early Saxon		410	197	9	616
	%Total	66.6%	32.0%	1.5%	-
Early-Middle Saxon		532	221	2	755
	%Total	70.5%	29.3%	0.3%	-
Middle Saxon		333	149	0	482
	%Total	69.1%	30.9%	0.0%	-
Middle-Late Saxon		464	178	0	642
	%Total	72.3%	27.7%	0.0%	-

6.3.3.2 Sex Distribution.

Table 6.3:16 shows the proportion of males and females for the Divided Sub-Periods of the Early Medieval period. The Middle-Late Saxon sample has the highest number of unsexed adults (22.2%), over double that of the Middle Saxon sample (10.2%). The only Divided Sub-Period that differed significantly from the expected equal distribution of males and females was the Early-Middle Saxon sample ($X^2 = 8.7309$, $p<0.005$, d.f. = 1; see Table 6.3:17), with a high proportion of females (58.9%). The proportion of males and females in this Divided Sub-Period was significantly different from the other three Divided Sub-Periods, none of which were significantly different from each other (see Table 6.3:18).

Table 6.3:16 Number and percentage of males, females and unsexed adults in the Early Saxon, Early-Middle Saxon, Middle Saxon, and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Period		Sex				
		Male	**Female**	**Unsexed**	**Total Sexed Adults**	**Total Adults**
Early Saxon		**172**	**168**	**70**	**340**	**410**
	%Total Adults	42.0%	41.0%	17.1%	82.9%	-
	%Sexed Adults	50.6%	49.4%	-	-	-
Early-Middle Saxon		**113**	**162**	**41**	**275**	**316**
	%Total Adults	35.8%	51.3%	13.0%	87.0%	-
	%Sexed Adults	41.1%	58.9%	-	-	-
Middle Saxon		**132**	**105**	**27**	**237**	**264**
	%Total Adults	50.0%	39.8%	10.2%	89.8%	-
	%Sexed Adults	55.7%	44.3%	-	-	-
Middle-Late Saxon		**192**	**169**	**103**	**361**	**464**
	%Total Adults	41.4%	36.4%	22.2%	77.8%	-
	%Sexed Adults	53.2%	46.8%	-	-	-

Table 6.3:17 Results of chi-square test comparing the proportions of males and females against an expected equal distribution in the Early Saxon, Early-Middle Saxon, Middle Saxon, and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Period		Male	Female	T	X^2	d.f.	Significant	p
Early Saxon	**O**	172	168	340	0.0470	1	No	$p>0.05$
	E	170	170					
Early-Middle Saxon	**O**	113	162	275	8.7309	1	**Yes**	$p<0.005$
	E	137.5	137.5					
Middle Saxon	**O**	132	105	237	3.0759	1	No	$p>0.05$
	E	118.5	118.5					
Middle-Late Saxon	**O**	192	169	361	1.4653	1	No	$p>0.05$
	E	180.5	180.5					

T = Total sexed adults; **d.f.** = degrees of freedom; **O** = Observed value; **E** = Expected value.

Table 6.3:18 Results of chi-square test comparing the proportions of males and females in pairs of periods in the Early Saxon, Early-Middle Saxon, Middle Saxon, and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medival Divided Sub-Periods Compared		X^2	d.f.	Significant	p
Early Saxon	Early-Middle Saxon	5.5148	1	Yes	$p<0.025$
Early Saxon	Middle Saxon	1.4617	1	No	$p>0.05$
Early Saxon	Middle-Late Saxon	0.4732	1	No	$p>0.05$
Early-Middle Saxon	Middle Saxon	10.8816	1	Yes	$p<0.001$
Early-Middle Saxon	Middle-Late Saxon	9.1487	1	Yes	$p<0.005$
Middle Saxon	Middle-Late Saxon	0.3633	1	No	$p>0.05$

d.f. = degrees of freedom.

6.3.3.3 Age Distribution.

6.3.3.3.1 Adults in General.

The sample for the Early-Middle Saxon Divided Sub-Period had the greatest proportion of Aged Adults (83.1%), followed by the Early Saxon Divided Sub-Period (77.3%). The proportion of Aged Adults in the Middle Saxon and Middle-Late Saxon Divided Sub-Periods were similar to each other (see Table 6.3:19).

Table 6.3:19 Number and percentage of adults in different age categories in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods)

Early Medieval Divided Sub-Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early Saxon	111	99	58	49	317	93	410
	35.0%	31.2%	18.3%	15.5%	77.3%	22.7%	
	210		107				100%
	66.2%		33.8%				
Early-Middle Saxon	111	125	99	107	442	90	532
	25.1%	28.3%	22.4%	24.2%	83.1%	16.9%	
	236		206				100%
	53.4%		46.6%				
Middle Saxon	63	65	49	50	227	106	333
	27.8%	28.6%	21.6%	22.0%	68.2%	31.8%	
	128		99				100%
	56.4%		43.6%				
Middle-Late Saxon	44	60	84	111	299	165	464
	14.7%	20.1%	28.1%	37.1%	64.4%	35.6%	
	104		195				100%
	34.8%		65.2%				
Total	329	349	290	317	1285	454	1739
	25.6%	27.2%	22.6%	24.7%	73.9%	26.1%	
	678		607				100%
	52.8%		47.2%				

The Early Saxon sample had a large proportion of adults in both youngest age categories (35.0% and 31.2%; 66.2% combined), with only 15.5% of the adults in the OA category and 33.8% in both oldest categories combined (see Table 6.3:19 and Figure 6.3:9). This distribution was significantly different from that for the Early-Middle Saxon and Middle-Late Saxon samples, but not the Middle Saxon sample (see Table 6.3:20). The Early-Middle Saxon sample had a much more even distribution between the age categories, but still had most individuals in the two youngest age categories (53.4%; see Table 6.3:19), and was also significantly different from the Middle-Late Saxon, but not the Middle Saxon, sample (see Table 6.3:20).

The Middle Saxon sample, which was not significantly different from either the Early Saxon or Early-Middle Saxon samples, was significantly different from the Middle-Late Saxon sample (see Table 6.3:20), and had a distribution between that for the Early Saxon and Early-Middle Saxon samples (see Table 6.3:19 and Figure 6.3:9). Again, most of the adults (56.4%) were found in the youngest two age categories, more than in the Early-Middle Saxon sample, but not as many as in the Early Saxon sample. The proportion of individuals in the YA and YMA groups was similar at 27.8% and 28.6% respectively, and the proportion of individuals in the two oldest age categories was also similar (OMA = 21.6% and OA = 22.0%). In contrast, the Middle-Late Saxon sample was significantly different from the other Divided Sub-Periods in terms of the proportions of individuals in each age category (see Table 6.3:20). Of all four Divided Sub-Periods, it was the only one to have a majority of individuals in the two oldest age categories (65.2%). It was almost a mirror image of the distribution in the Early Saxon sample, with 37.1% of the adults in the OA and only 14.7% in the YA categories.

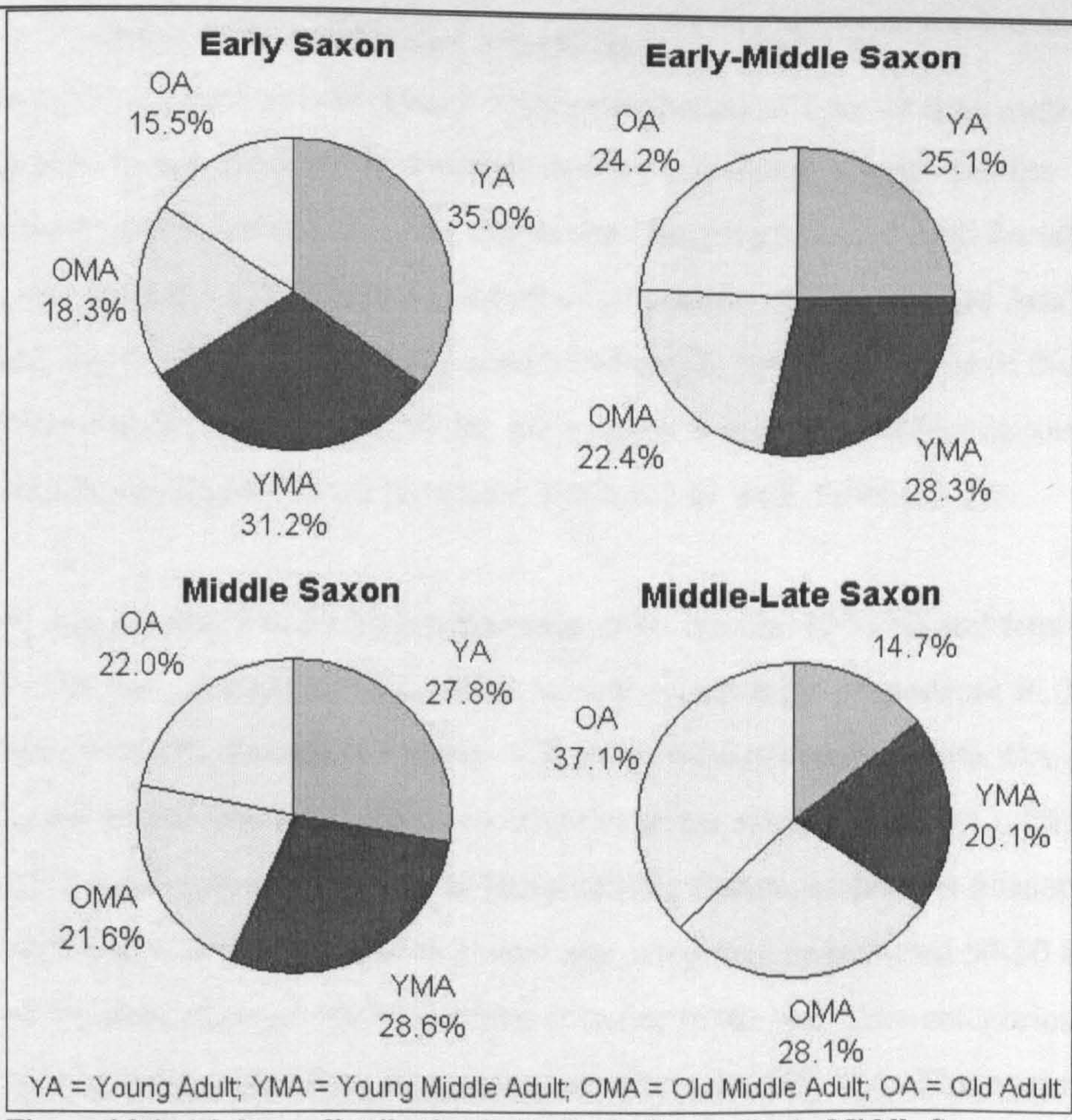


Figure 6.3:9 Adult age distribution in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Table 6.3:20 Results of Kolmogorov-Smirnov tests comparing adult age distributions between the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Periods Compared	Maximum Observed Difference	Dmax Significance Level		Significant ?
Early Saxon/ Early-Middle Saxon	-0.1285	Dmax 0.005	0.1273	**Yes**
Early Saxon/ Middle Saxon	-0.0986	Dmax 0.05	0.1183	No
Early Saxon/ Middle-Late Saxon	-0.3146	Dmax 0.001	0.1572	**Yes**
Early-Middle Saxon/ Middle Saxon	0.0299	Dmax 0.05	0.1111	No
Early-Middle Saxon/ Middle-Late Saxon	-0.1861	Dmax 0.001	0.1460	**Yes**
Middle Saxon/ Middle-Late Saxon	-0.2161	Dmax 0.001	0.1717	**Yes**

6.3.3.3.2 Adults: Male and Female Subdivisions.

For three of the Divided Sub-Periods, a higher proportion of females than males could be assigned to an age category. It was only in the Early Saxon sample that the proportion of aged males (82.6%) was higher than the proportion of aged females (79.2%; see Table 6.3:21). There was a higher proportion of female Aged Adults than in the total Aged Adults in all four Divided Sub-Periods but in only three of the Divided Sub-Periods for the male adults, the exception being the Middle Saxon male sample which was slightly lower (compare Table 6.3:21 with Table 6.3:19).

The Early Saxon sample had a high percentage of both males (64.1%) and females (63.9%) in the two younger age categories, with similarly large proportions in the YA group (Male = 31.0%, Female = 34.6%). The proportion of females in the OA group, at 19.5%, was higher than the proportion of males in the same category (13.4%; see Table 6.3:21 and Figure 6.3:10). In the Early-Middle Saxon sample, the proportion of individuals in the two younger and two older age categories approached 50-50 for both males and females, although the percentage of males in the two older categories (50.5%) was slightly higher than the proportion of females (48.3%). There was a larger percentage of males (30.3%) in the OA group compared to females (24.8%), whereas the females had more individuals in the YA group (25.5%) than did the males (20.2%).

In the Middle Saxon sample, there was a slightly higher proportion of females (50.6%) than males (46.6%) in the two older categories, with a larger percentage of females in the OA group (28.6%) than males (21.6%). The proportion of males and females in the YA group was similar, at 23.9% and 24.7% respectively (see Table 6.3:21 and Figure 6.3:10). The Middle-Late Saxon sample contrasts strongly with the Early Saxon sample. A large proportion of both males and females was found in the two older age groups, especially for the males (Male = 71.3%, Female = 60.4%). In both sexes the age category with the most individuals was the OA group, where 38.0% of the males and 36.0% of the females were placed. Only 10.0% of the males were assigned to the YA category, compared to 19.4% of the females.

Overall, within each of the Divided Sub-Periods, the distribution of males and females across the age categories was similar to each other, and were found not to be significantly different (see Table 6.3:22).

Table 6.3:21 Number and percentage of males and females in different age categories in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Period		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early Saxon	Male	44	47	32	19	142	30	172
		31.0%	33.1%	22.5%	13.4%	82.6%	17.4%	
		91		51				100%
		64.1%		35.9%				
	Female	46	39	22	26	133	35	168
		34.6%	29.3%	16.5%	19.5%	79.2%	20.8%	
		85		48				100%
		63.9%		36.1%				
Early-Middle Saxon	Male	20	29	20	30	99	14	113
		20.2%	29.3%	20.2%	30.3%	87.6%	12.4%	
		49		50				100%
		49.5%		50.5%				
	Female	38	39	35	37	149	13	162
		25.5%	26.2%	23.5%	24.8%	92.0%	8.0%	
		77		72				100%
		51.7%		48.3%				
Middle Saxon	Male	21	26	22	19	88	44	132
		23.9%	29.5%	25.0%	21.6%	66.7%	33.3%	
		47		41				100%
		53.4%		46.6%				
	Female	19	19	17	22	77	28	105
		24.7%	24.7%	22.1%	28.6%	73.3%	26.7%	
		38		39				100%
		49.4%		50.6%				
Middle-Late Saxon	Male	15	28	50	57	150	42	192
		10.0%	18.7%	33.3%	38.0%	78.1%	21.9%	
		43		107				100%
		28.7%		71.3%				
	Female	27	28	34	50	139	30	169
		19.4%	20.1%	24.5%	36.0%	82.2%	17.8%	
		55		84				100%
		39.6%		60.4%				
Totals	Male	100	130	124	125	479	130	609
		20.9%	27.1%	25.9%	26.1%	78.7%	21.3%	
		230		249				100%
		48.0%		52.0%				
	Female	130	125	108	135	498	106	604
		26.1%	25.1%	21.7%	27.1%	82.5%	17.5%	
		255		243				100%
		51.2%		48.8%				

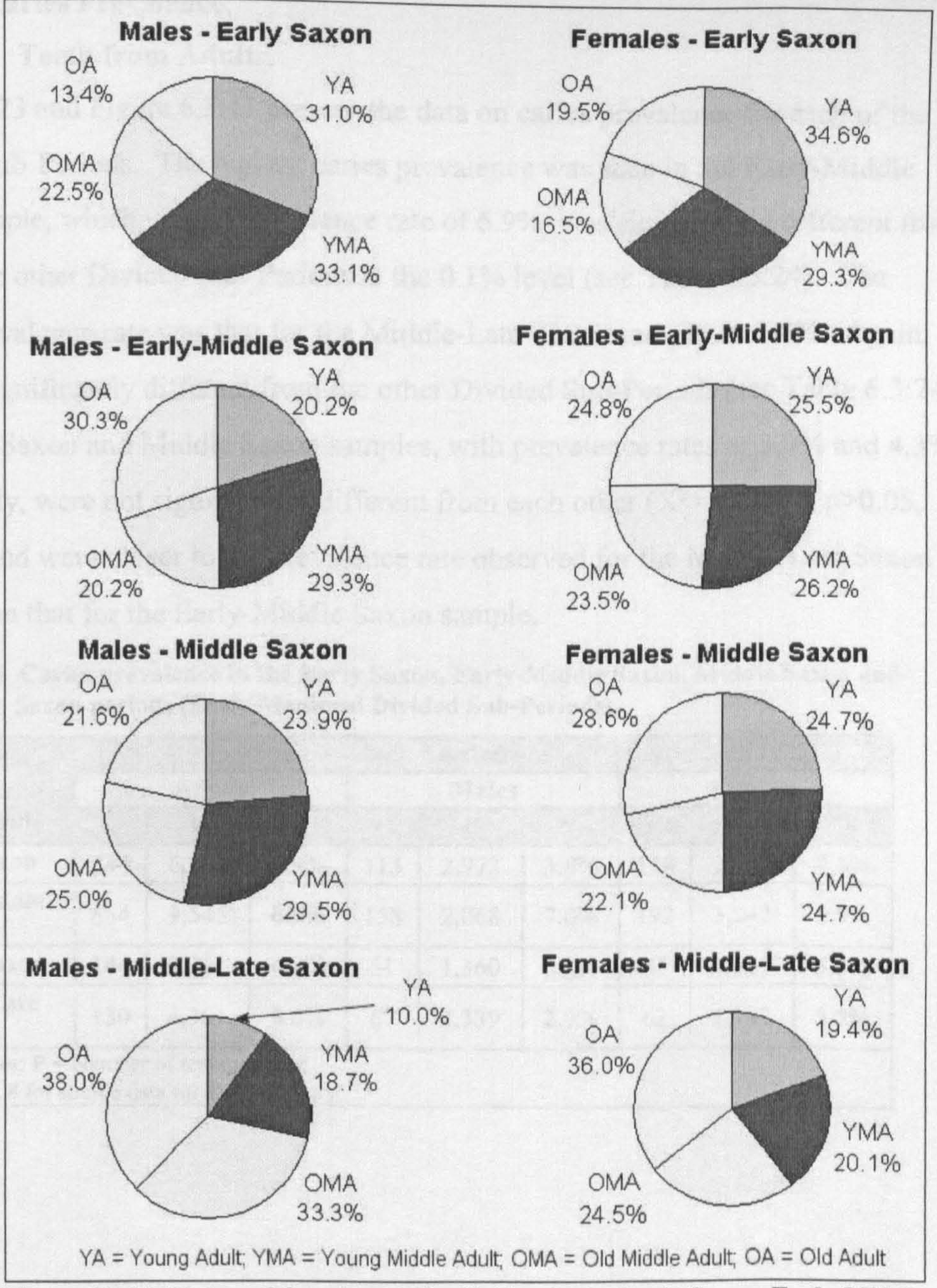


Figure 6.3:10 Male and female age distribution in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Table 6.3:22 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Male/Female Compared	Dmax observation	Dmax Significance level		Significant ?
Early Saxon	0.0617	Dmax 0.05	0.1641	No
Early-Middle Saxon	-0.0547	Dmax 0.05	0.1763	No
Middle Saxon	0.0698	Dmax 0.05	0.2122	No
Middle-Late Saxon	0.109	Dmax 0.05	0.1601	No

6.3.3.4 Caries Prevalence.

6.3.3.4.1 Teeth from Adults.

Table 6.3:23 and Figure 6.3:11 present the data on caries prevalence for each of the Divided Sub-Periods. The highest caries prevalence was seen in the Early-Middle Saxon sample, which, with a prevalence rate of 6.9%, was significantly different from each of the other Divided Sub-Periods at the 0.1% level (see Table 6.3:24). The lowest prevalence rate was that for the Middle-Late Saxon sample, at 3.0%. Again, this was significantly different from the other Divided Sub-Periods (see Table 6.3:24). The Early Saxon and Middle Saxon samples, with prevalence rates of 3.9% and 4.3% respectively, were not significantly different from each other ($X^2 = 0.8371$, $p>0.05$, d.f. = 1), and were closer to the prevalence rate observed for the Middle-Late Saxon sample than that for the Early-Middle Saxon sample.

Table 6.3:23 Caries prevalence in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Early Saxon	244	6,261	3.9%	113	2,973	3.8%	118	2,747	4.3%
Early-Middle Saxon	654	9,545	6.9%	158	2,068	7.6%	192	3,242	5.9%
Middle Saxon	144	3,363	4.3%	51	1,360	3.8%	54	1,021	5.3%
Middle-Late Saxon	130	4,301	3.0%	67	2,339	2.9%	62	1,942	3.2%

C = With Caries; P = Number of teeth present.
See **Appendix 8** for source data for each category.

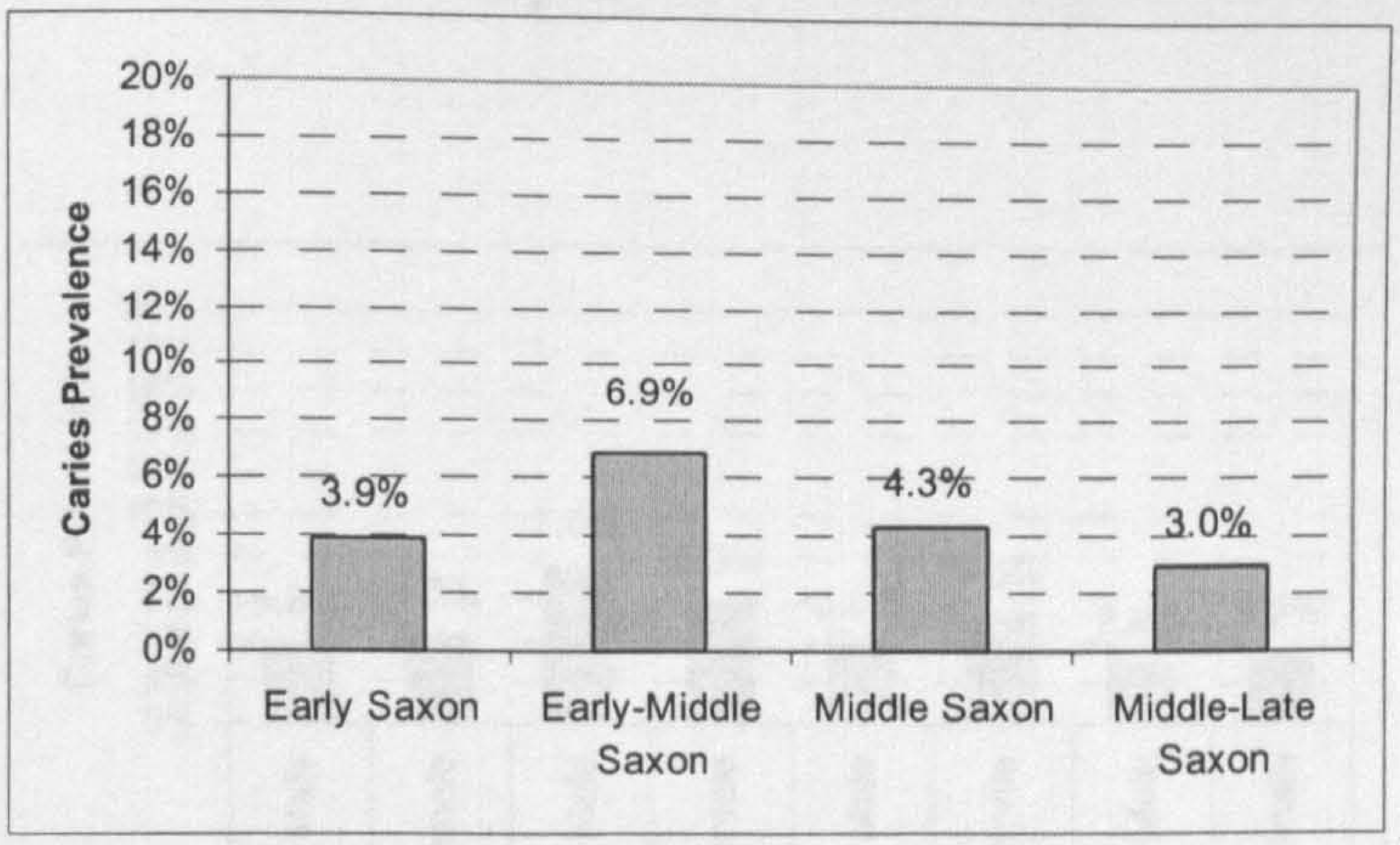


Figure 6.3:11 Caries prevalence in adult teeth in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Table 6.3:24 Results of chi-square test comparing caries prevalence (adult teeth) in pairs of periods - Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Early Medieval Divided Sub-Periods Compared		X^2	d.f.	Significant	p
Early Saxon	Early-Middle Saxon	61.5953	1	Yes	p<0.001
Early Saxon	Middle Saxon	0.8371	1	No	p>0.05
Early Saxon	Middle-Late Saxon	5.7096	1	Yes	p<0.025
Early-Middle Saxon	Middle Saxon	28.3162	1	Yes	p<0.001
Early-Middle Saxon	Middle-Late Saxon	81.3880	1	Yes	p<0.001
Middle Saxon	Middle-Late Saxon	8.6824	1	Yes	p<0.005
d.f. = degrees of freedom.					

6.3.3.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rate in both male and female teeth was highest in the Early-Middle Saxon sample (Male = 7.6%, Female = 5.9%), and lowest in the Middle-Late Saxon sample (Male = 2.9%, Female = 3.2%; see Table 6.3:23 and Figure 6.3:12), which reflects the results for the adult teeth described above. As for the adult teeth, the male teeth caries prevalence of the Early-Middle Saxon sample was found to be significantly different from the caries prevalence in the male teeth from all other Divided Sub-Periods (see Table 6.3:25). However, although the caries prevalence for female teeth in the Early-Middle Saxon sample was also significantly different from the Early Saxon and Middle-Late Saxon samples, it was found not to be significantly different from the Middle Saxon sample.

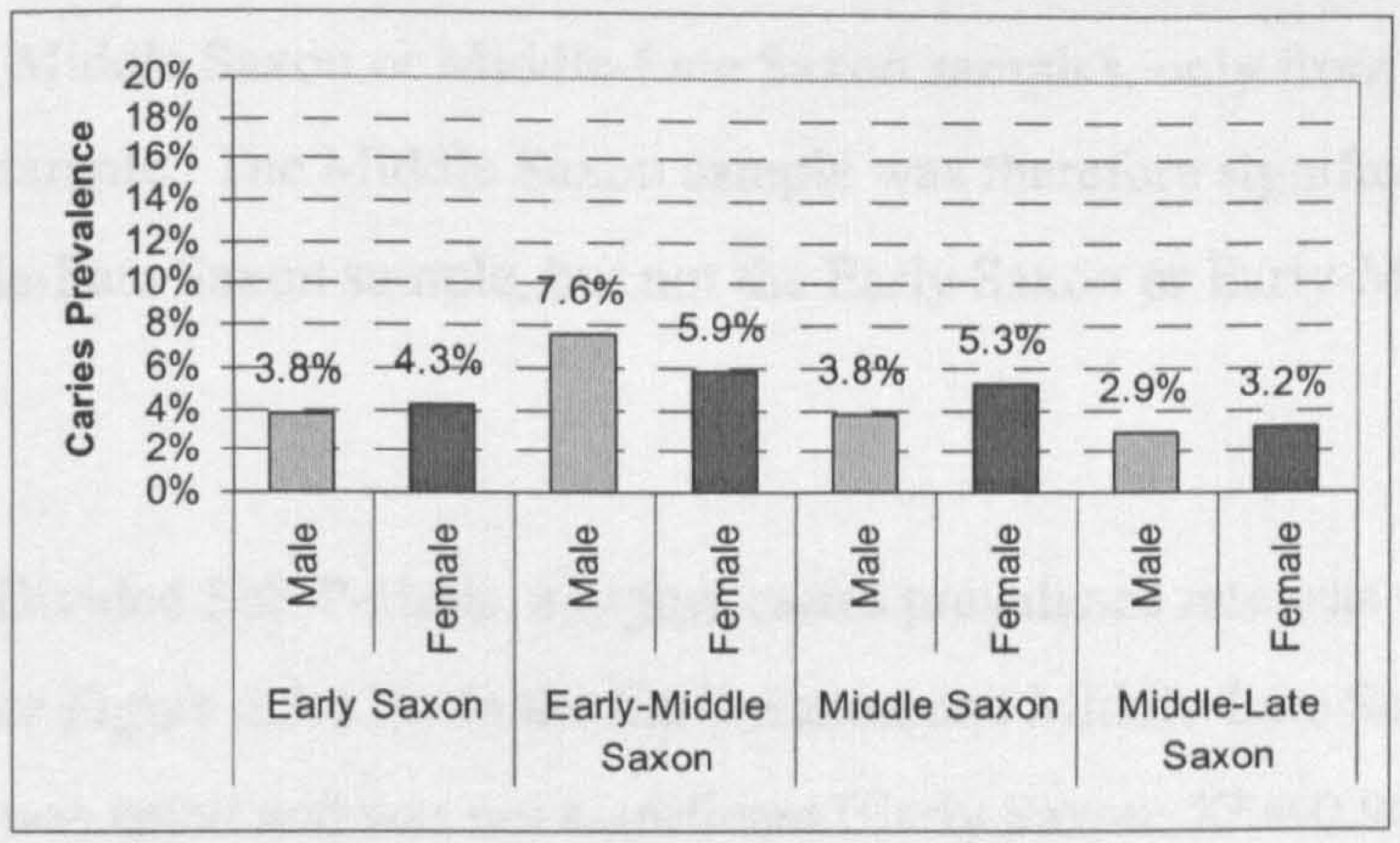


Figure 6.3:12 Caries prevalence in male and female teeth in the Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods).

Table 6.3:25 Comparison of caries prevalence in male and female teeth between pairs of Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon periods (Early Medieval Divided Sub-Periods): chi-square values and significance level.

Early Medieval Divided Sub-Periods Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Early Saxon	Early-Middle Saxon	35.3420	1	p<0.001	8.0167	1	p<0.005
Early Saxon	Middle Saxon	0.0066	1	p>0.05	1.6859	1	p>0.05
Early Saxon	Middle-Late Saxon	3.5063	1	p>0.05	3.7497	1	p>0.05
Early-Middle Saxon	Middle Saxon	21.6877	1	p<0.001	0.5728	1	p>0.05
Early-Middle Saxon	Middle-Late Saxon	51.6705	1	p<0.001	19.4210	1	p<0.001
Middle Saxon	Middle-Late Saxon	2.1836	1	p>0.05	7.8179	1	p<0.01

d.f. = degrees of freedom.

For the male teeth, the caries prevalence was not significantly different between the Early Saxon, Middle Saxon and Middle-Late Saxon samples; only the Early-Middle Saxon sample had a significantly different caries prevalence rate (see Table 6.3:25). The pattern was more complicated for the female teeth. The sample with the lowest caries prevalence, the Middle-Late Saxon sample (3.2%), was not significantly different from the Early Saxon sample (4.3%), but was significantly different from both the Middle Saxon (5.3%) and Early-Middle Saxon (5.9%) samples (see Table

6.3:23). The Early-Middle Saxon sample was not significantly different from the Middle Saxon sample, but was significantly different from both the Early Saxon and Middle-Late Saxon samples. The Early Saxon sample was not significantly different from either the Middle Saxon or Middle-Late Saxon samples, only from the Early-Middle Saxon sample. The Middle Saxon sample was therefore significantly different from the Middle-Late Saxon sample, but not the Early Saxon or Early-Middle Saxon samples.

In three of the Divided Sub-Periods, a higher caries prevalence rate was seen in the female teeth (see Figure 6.3:12). In the Early Saxon and Middle-Late Saxon samples this difference was small and was not significant (Early Saxon: $X^2 = 0.9017$, $p>0.05$, d.f. = 1; Middle-Late Saxon: $X^2 = 0.3909$, $p>0.05$, d.f. = 1). A slightly larger difference was observed in the Middle Saxon sample, where the female teeth had a caries prevalence of 5.3% and the male teeth had a prevalence of 3.8%, but, again, this was not found to be statistically significant ($X^2 = 3.2764$, $p>0.05$, d.f. = 1). The only Divided Sub-Period where there was a significant difference between caries prevalence in male and female teeth was the Early-Middle Saxon sample, where the male teeth had a higher caries prevalence rate (7.6%) than the female teeth (5.9%; $X^2 = 6.0525$, $p<0.025$, d.f. = 1).

6.3.4 Middle Medieval Sub-Periods: Late Saxon; Early-Late Medieval.

6.3.4.1 Proportions of Adults and Subadults.

The Late Saxon Sub-Period had almost double the number of skeletons of the Early-Late Medieval Sub-Period, but had proportionately fewer adults (61.4%) and more subadults (38.4%) in the sample (see Table 6.3:26). These proportions diverge from the pattern of c. 70% adults and 30% subadults noted for most periods above, and which can be seen to occur again in the Early-Late Medieval sample (69.8% adults: 30.2% subadults).

Table 6.3:26 Number of adult, subadult and unaged individuals in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Middle Medieval Sub-Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Late Saxon		538	336	2	876
	%Total	61.4%	38.4%	0.2%	-
Early-Late Medieval		339	147	0	486
	%Total	69.8%	30.2%	0.0%	-

6.3.4.2 Sex Distribution.

It can be seen from Table 6.3:27 that the sample size of males and females for the Early-Late Medieval sample was considerably smaller than for the Late Saxon sample. Only two data-sets provided data on caries prevalence in teeth from males and females for the Early-Late Medieval Sub-Period, compared to four for the Late Saxon Sub-Period. Despite this discrepancy, the proportion of males and females in the two Sub-Periods of the Middle Medieval period is virtually identical, with 55% males and 45% females in each group (see Table 6.3:27). There was no significant difference between the two samples with respect to proportions of males and females ($X^2 = 0.0007$, $p>0.05$, d.f. = 1). However, although the proportions of sexed individuals in the Early-Late Medieval sample were not significantly different from that normally expected ($X^2 = 1.0638$, $p>0.05$, d.f. = 1), the proportions in the Late Saxon sample did differ significantly from an equal distribution at the 5% level ($X^2 = 4.9655$, $p<0.05$, d.f. = 1).

Table 6.3:27 Number and percentage of males, females and unsexed adults in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Middle Medieval Sub-Period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Late Saxon		256	208	34	464	498
	%Total Adults	51.4%	41.8%	6.8%	93.2%	-
	%Sexed Adults	55.2%	44.8%	-	-	-
Early-Late Medieval		52	42	7	94	101
	%Total Adults	51.5%	41.6%	6.9%	93.1%	-
	%Sexed Adults	55.3%	44.7%	-	-	-

6.3.4.3 Age Distribution.

6.3.4.3.1 Adults in General.

The Late Saxon sample had a slightly higher proportion of Aged Adults (78.8%) than the Early-Late Medieval sample (75.9%; see Table 6.3:28). Both samples had proportionally fewer individuals in the two oldest age groups (Late Saxon = 47.6%, Early-Late Medieval = 31.7%), but the Early-Late Medieval sample had a particularly low percentage of individuals in the OA group (8.7%) compared to the Late Saxon sample (17.7%). The Early-Late Medieval sample also had a much higher percentage of individuals in the YA group (39.4%) than did the Late Saxon sample (24.1%; see Table 6.3:28 and Figure 6.3:13). The age distributions were significantly different from each other (D_{MAXobs} 0.1591, $D_{MAX\ 0.05}$ 0.1488).

Table 6.3:28 Number and percentage of adults in different age categories in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Middle Medieval Sub-Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Late Saxon	102	120	127	75	424	114	538
	24.1%	28.3%	30.0%	17.7%	78.8%	21.2%	
	222		202				100%
	52.4%		47.6%				
Early-Late Medieval	41	30	24	9	104	33	137
	39.4%	28.8%	23.1%	8.7%	75.9%	24.1%	❶
	71		33				100%
	68.3%		31.7%				
Total	143	150	151	84	528	147	675
	27.1%	28.4%	28.6%	15.9%	78.2%	21.8%	❶
	293		235				100%
	55.5%		44.5%				

These data exclude - ❶ 202 adults from Trowbridge, as they are only placed in two broad categories.

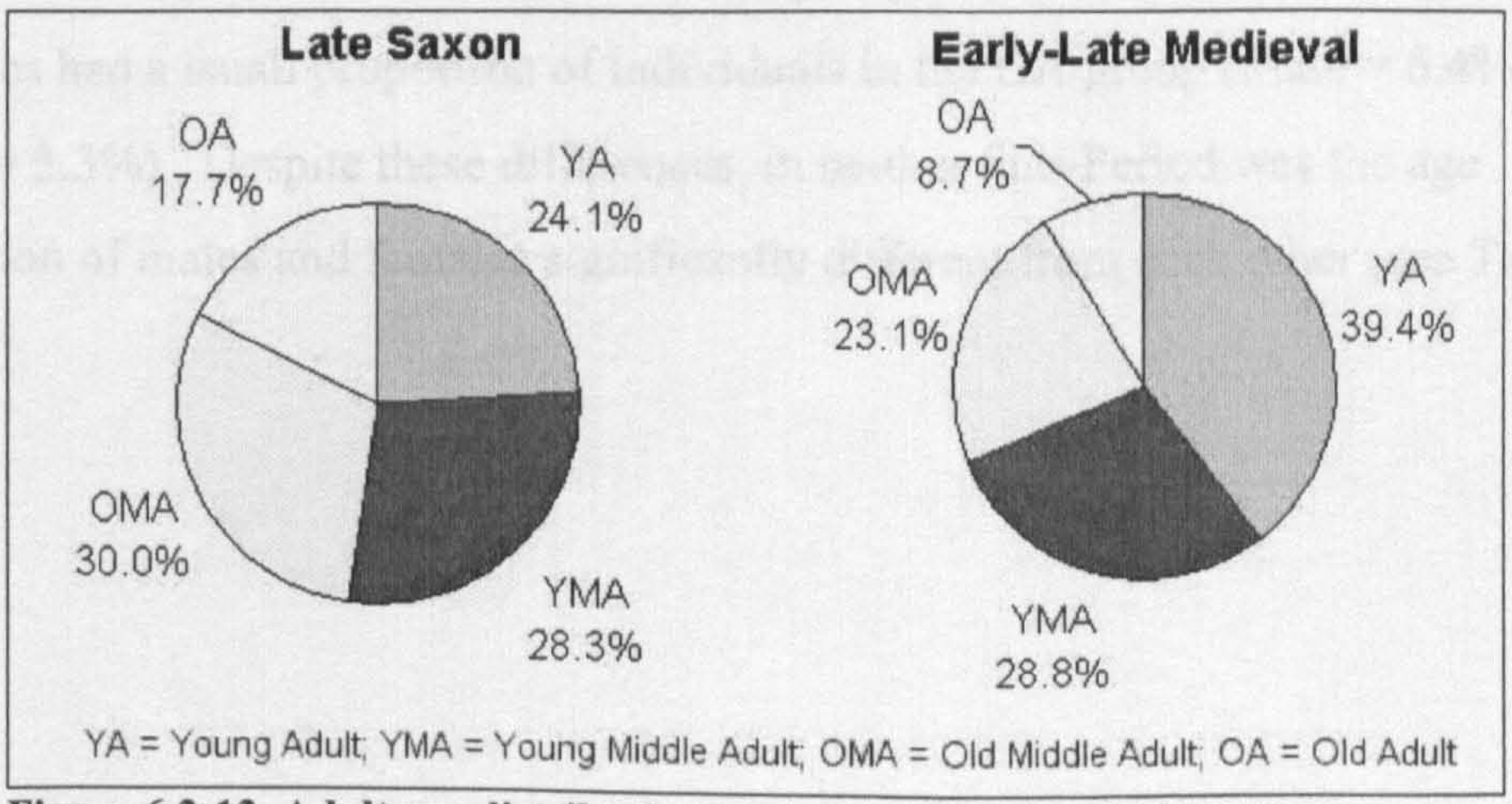


Figure 6.3:13 Adult age distribution in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

6.3.4.3.2 Adults: Male and Female Subdivisions.

Similar proportions of males (82.4%) and females (81.7%) had been aged in the Late Saxon sample, a higher proportion than had been aged in the total adults at 78.8% (compare Table 6.3:29 with Table 6.3:28). In contrast, a large proportion of the Early-Late Medieval males had been aged (90.4%), but for the females this proportion was only 71.4% (see Table 6.3:29). The males, therefore, followed the trend of the previous samples in having a higher proportion of aged individuals than the total adults (75.9%), but the females did not.

In the Late Saxon Sub-Period most of the females had been placed in the two younger age categories (61.2%), with 30.6% in the YA category, whereas 47.4% of the males were assigned to these two groups, and only 20.9% were classed as YA (see Table 6.3:29 and Figure 6.3:14). There were proportionally more males in the OA (20.9%) and OMA (31.8%) categories than females (12.9% and 25.9% respectively).

Some differences between the male and female age distributions could also be noted in the Early-Late Medieval sample (see Table 6.3:29 and Figure 6.3:14). Just under half of the males (46.8%) were placed in the YA group, which, when combined with the 27.7% in the YMA group, resulted in three quarters (74.5%) of the males being assigned to the two younger age groups. Although a third (33.3%) of the females were categorised as YA, and more were found in the two younger age groups (56.7%) than the old (43.3%), this proportion was not as extreme as that of the male sample. There were considerably more females in the OMA group (40.0%) than males (19.1%), but both sexes had a small proportion of individuals in the OA group (Male = 6.4%, Female = 3.3%). Despite these differences, in neither Sub-Period was the age distribution of males and females significantly different from each other (see Table 6.3:30).

Table 6.3:29 Number and percentage of males and females in different age categories in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Middle Medieval Sub-Period		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Late Saxon	Male	44	56	67	44	211	45	256
		20.9%	26.5%	31.8%	20.9%	82.4%	17.6%	
		100		111				100%
		47.4%		52.6%				
	Female	52	52	44	22	170	38	208
		30.6%	30.6%	25.9%	12.9%	81.7%	18.3%	
		104		66				100%
		61.2%		38.8%				
Early-Late Medieval	Male	22	13	9	3	47	5	52
		46.8%	27.7%	19.1%	6.4%	90.4%	9.6%	
		35		12				100%
		74.5%		25.5%				
	Female	10	7	12	1	30	12	42
		33.3%	23.3%	40.0%	3.3%	71.4%	28.6%	
		17		13				100%
		56.7%		43.3%				
Totals	Male	66	69	76	47	258	50	308
		25.6%	26.7%	29.5%	18.2%	83.8%	16.2%	
		135		123				100%
		52.3%		47.7%				
	Female	62	59	56	23	200	50	250
		31.0%	29.5%	28.0%	11.5%	80.0%	20.0%	
		121		79				100%
		60.5%		39.5%				

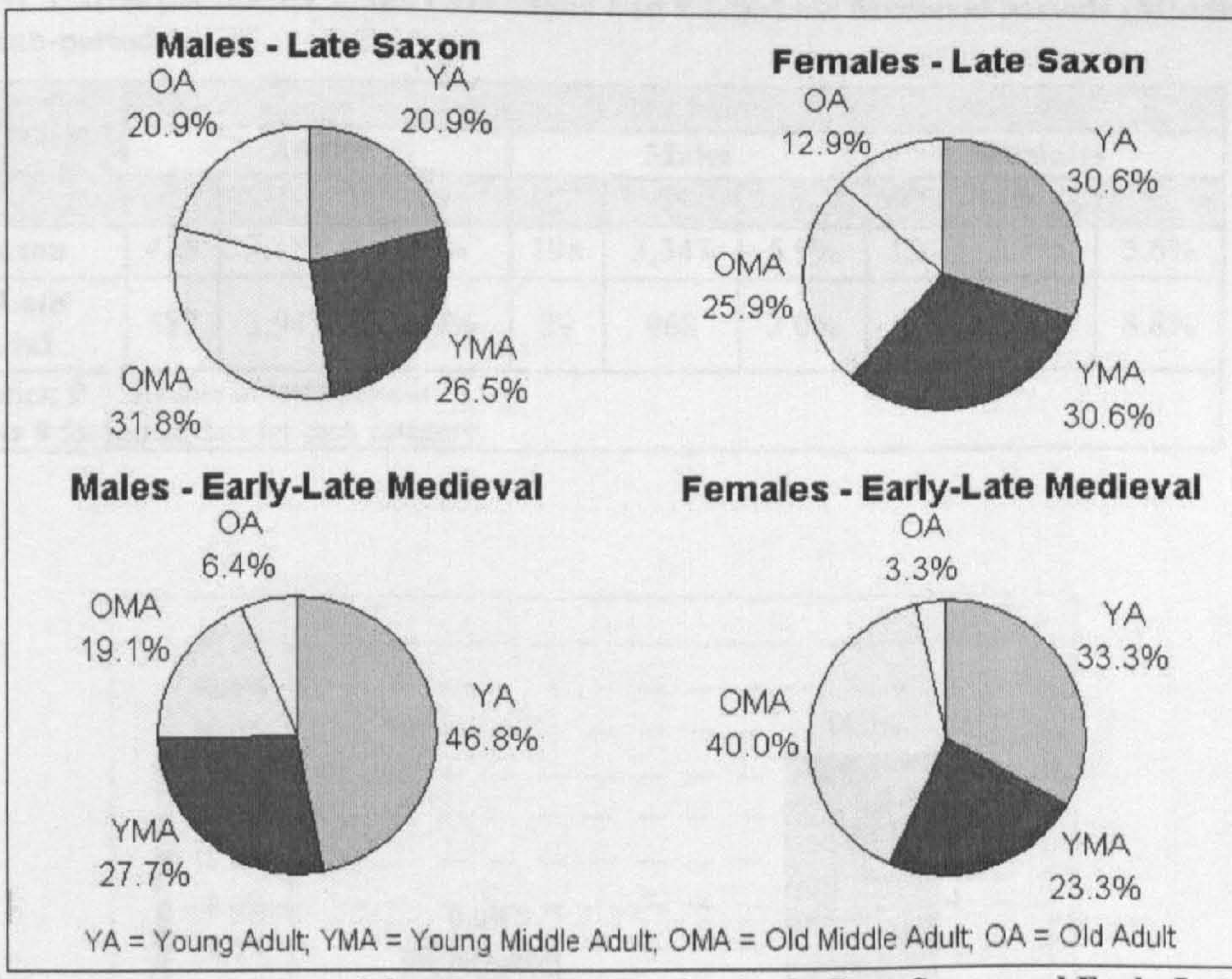


Figure 6.3:14 Male and female age distribution in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Table 6.3:30 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Late Saxon	0.1378	Dmax 0.05	0.1402	No
Early-Late Medieval	0.1780	Dmax 0.05	0.3178	No

6.3.4.4 Caries Prevalence.

6.3.4.4.1 Teeth from Adults.

There was a dramatic difference in caries prevalence between the two Middle Medieval Sub-Periods, with the Early-Late Medieval sample having over double the caries prevalence observed in the Late Saxon sample (see Table 6.3:31 and Figure 6.3:15). This difference was found to be significant ($X^2 = 240.0568$, $p<0.001$, d.f. = 1).

Table 6.3:31 Caries prevalence in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

Middle Medieval Sub-Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Late Saxon	433	7,181	6.0%	198	3,347	5.9%	156	2,796	5.6%
Early-Late Medieval	587	3,941	14.9%	29	968	3.0%	49	560	8.8%

C = With Caries; **P** = Number of teeth present.
See **Appendix 9** for source data for each category.

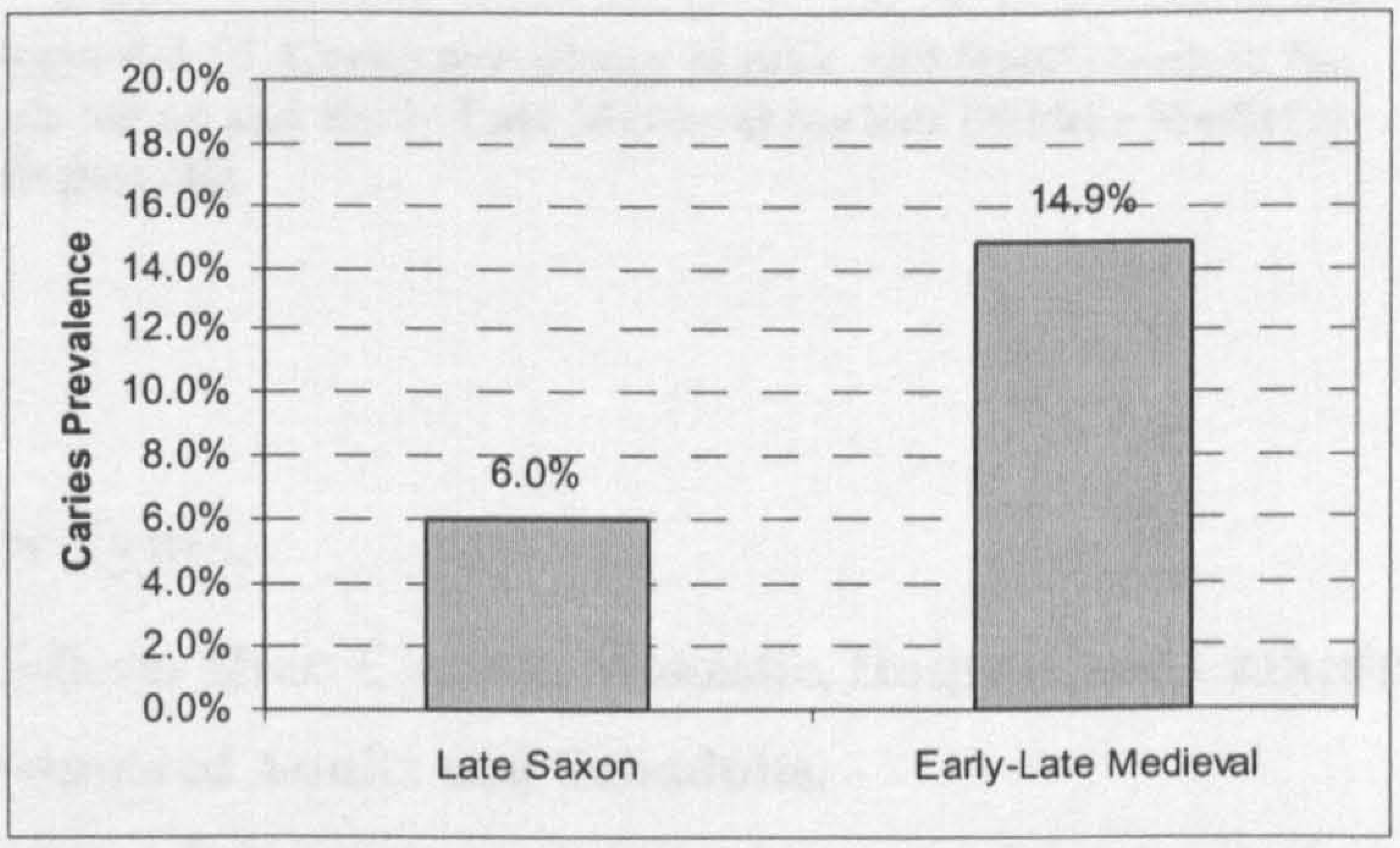


Figure 6.3:15 Caries prevalence in adult teeth in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

6.3.4.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rates in the male and female teeth in the Late Saxon sample were not significantly different from each other. However, the female teeth from the Early-Late Medieval sample had a markedly higher caries prevalence rate (8.8%) than the male teeth (3.0%; see Table 6.3:31 and Figure 6.3:16), and this difference was significant ($X^2 = 24.2484$, $p<0.001$, d.f. = 1).

An increase in caries prevalence was seen in the female teeth from 5.6% in the Late Saxon Sub-Period to 8.8% in the Early-Late Medieval Sub-Period (see Figure 6.3:16), significant at the 0.5% level ($X^2 = 8.1776$, $p<0.005$, d.f. = 1), which reflects the pattern observed in the adult teeth. In contrast, the male teeth showed a reduction in caries prevalence, from 5.9% in the Late Saxon Sub-Period to 3.0% in the Early-Late Medieval Sub-Period. Again, this difference was statistically significant ($X^2 = 12.8441$, $p<0.001$, d.f. = 1).

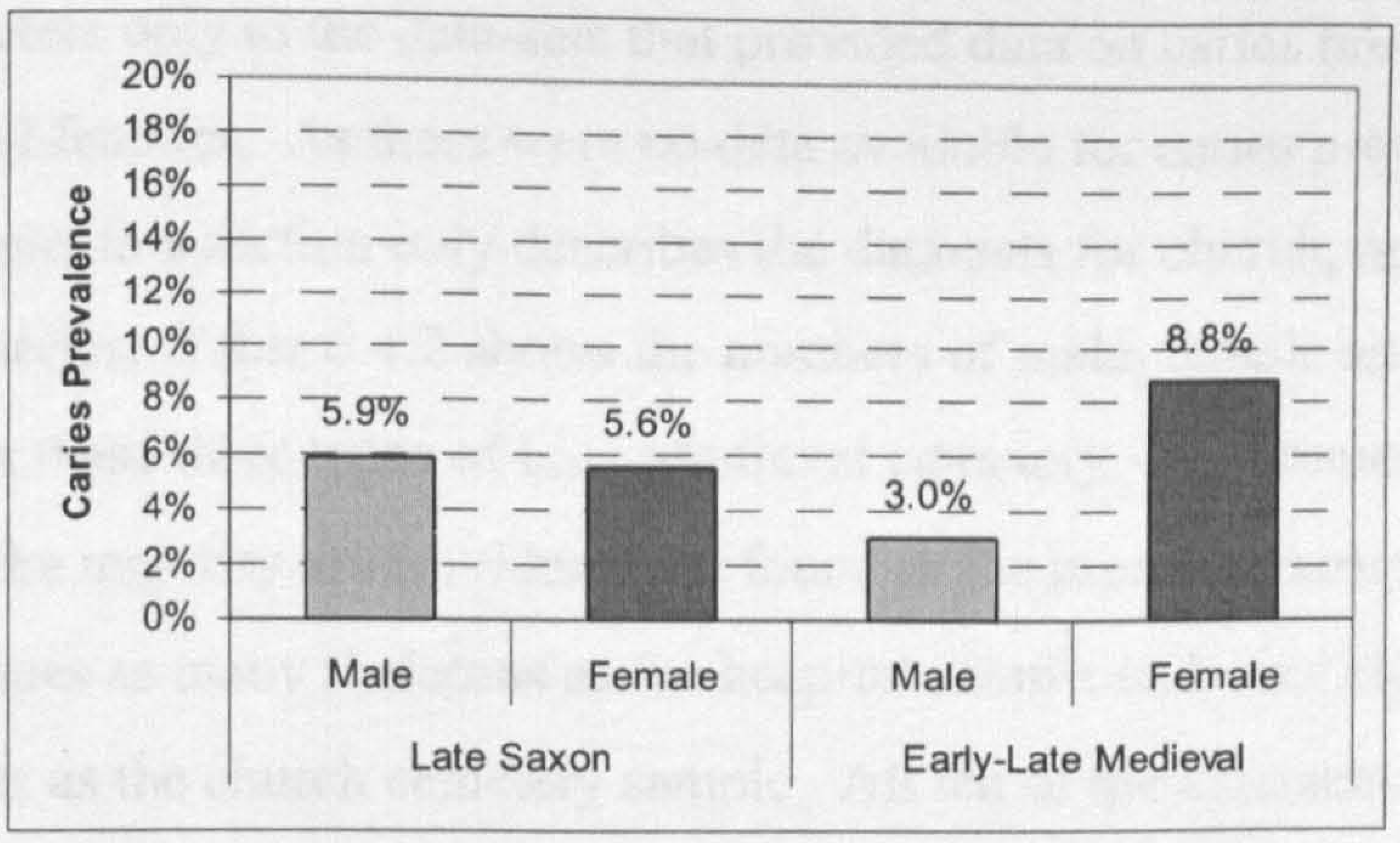


Figure 6.3:16 Caries prevalence in male and female teeth in the Late Saxon and Early-Late Medieval periods (Middle Medieval sub-periods).

6.4 Cemetery Types.

6.4.1 Late Medieval Sites: Church, Monastic, Hospital and Cathedral.

6.4.1.1 Proportions of Adults and Subadults.

The largest numbers of skeletons came from the monastic and cathedral sites, even though the latter consisted of only one data-set. The smallest sample came from the hospital sites (see Table 6.4:1). The cathedral and church cemeteries had proportions of adults and subadults close to 70% and 30% respectively. The monastic and hospital cemeteries had a considerably higher proportion of adults close to 75% and 80% respectively and a lower proportion of subadults c. 25% and 20% respectively.

Table 6.4:1 Number of adult, subadult and unaged individuals in the church, monastic, hospital and cathedral Late Medieval cemetery types.

Late Medieval Cemetery Type		Age			Total Skeletons
		Adult	Subadult	Unaged	
Church		930	366	3	1299 ➊
	%Total	71.6%	28.2%	0.2%	-
Monastic		1270	417	2	1689
	%Total	75.2%	24.7%	0.1%	-
Hospital		539	132	0	671
	%Total	80.3%	19.7%	0.0%	-
Cathedral		1093	512	0	1605
	%Total	68.1%	31.9%	0.0%	-

These data exclude - ➊ 146 skeletons from the Isle of Ensay data-set, as there were no data for numbers of adults and subadults.

6.4.1.2 Sex Distribution.

This section refers only to the data-sets that provided data on caries prevalence in teeth from males and females. As there were no data available for caries prevalence in the cathedral sample, this section only describes the data-sets for church, monastic and hospital cemeteries. Table 6.4:2 shows the numbers of male, female and unsexed skeletons from these three types of Late Medieval cemetery. It is immediately apparent that the majority of individuals are found in the monastic sample, which has nearly three times as many skeletons as the hospital sample and over eight times as many skeletons as the church cemetery sample. All ten of the data-sets for monastic cemeteries provided data on caries prevalence in male and female teeth, whereas three of the data-sets for church cemeteries and one of those for the hospital cemeteries did not, leaving four church data-sets and two hospital data-sets that did give data for male and female teeth.

Table 6.4:2 Number and percentage of males, females and unsexed adults in church, monastic and hospital Late Medieval cemetery types.

Late Medieval Cemetery Type		Sex: Male	Sex: Female	Sex: Unsexed	Total Sexed Adults	Total Adults
Church		**57**	**66**	**30**	**123**	**153**
	%Total Adults	37.3%	43.1%	19.6%	80.4%	-
	%SexedAdults	46.3%	53.7%	-	-	-
Monastic		**731**	**373**	**166**	**1104**	**1270**
	%Total Adults	57.6%	29.4%	13.1%	86.9%	-
	%SexedAdults	66.2%	33.8%	-	-	-
Hospital		**274**	**151**	**27**	**425**	**452**
	%Total Adults	60.6%	33.4%	6.0%	94.0%	-
	%SexedAdults	64.5%	35.5%	-	-	-

NB. There was no caries prevalence data in the Cathedral sample.

Table 6.4:3 Results of chi-square test comparing the proportions of males and females against an expected equal distribution in church, monastic and hospital Late Medieval cemetery types.

Late Medieval Cemetery Type		Male	Female	Total	X^2	d.f.	Significant	p
Church	O	57	66	123	0.6585	1	No	$p>0.05$
	E	61.5	61.5					
Monastic	O	731	373	1104	116.0906	1	**Yes**	$p<0.001$
	E	552	552					
Hospital	O	274	151	425	35.5977	1	**Yes**	$p<0.001$
	E	212.5	212.5					

d.f. = degrees of freedom; **O** = Observed value; **E** = Expected value.

The church cemeteries had the largest proportion of unsexed adults (19.6%), and show a pattern similar to that of the Early Medieval period with almost equal proportions of males and females (compare Table 6.4:2 with Table 6.3:2). This proportion of males and females does not differ significantly from the equal distribution expected in a normal population (see Table 6.4:3). In contrast, the hospital and monastic cemeteries show a different pattern, with a greater preponderance of males: 64.5% in the hospital cemeteries, and 66.2% in the monastic cemeteries. The proportion of the sexes in both cemetery types is significantly different from the usual even distribution (see Table 6.4:3). All the individual monastic cemeteries, with the exception of Linlithgow, had a higher proportion of males. There was no significant difference between the proportions of males and females in the monastic and hospital cemeteries, but there was a significant difference between the proportions of males and females in the church cemeteries and both the monastic and hospital cemeteries (see Table 6.4:4).

Table 6.4:4 Results of chi-square test comparing the proportions of males and females in pairs of church, monastic and hospital Late Medieval cemetery types.

Late MedievalCemetery Types Compared		X^2	d.f.	Significant	p
Church	Monastic	19.0206	1	**Yes**	p<0.001
Church	Hospital	13.1081	1	**Yes**	p<0.001
Monastic	Hospital	0.4140	1	No	p>0.05

d.f. = degrees of freedom.

6.4.1.3 Age Distribution.

6.4.1.3.1 Adults in General.

Of the four different cemetery types, the hospital cemeteries had the largest proportion of Aged Adults (84.2%) and the church cemeteries had the smallest (66.5%). The monastic and cathedral cemeteries were similar, with 74.3% (monastic) and 73.5% (cathedral) of the adults in each sample being allocated to an age category (see Table 6.4:5).

The hospital and cathedral samples were both significantly different from all other cemetery types in terms of age distribution (see Table 6.4:6). The hospital sample had large proportions of individuals in both the YA and OA categories (28.2% and 31.3% respectively). The cathedral sample had a particularly unusual age distribution with a large proportion of individuals in the middle two age categories (YMA = 42.2% and OMA = 34.2%), compared to the small proportion found in both youngest (13.3%) and oldest (10.3%) categories. Overall, there were fewer individuals in the oldest two age categories for both cemetery types, with the cathedral sample having 44.5%, and the hospital sample having 48.7% (see Table 6.4:5 and Figure 6.4:1).

The church and monastic cemeteries were not significantly different from each other (see Table 6.4:6). Both had a small proportion of individuals in the YA category (15.5% and 18.2%), and both had around a quarter of their individuals in the OA category (26.1% and 23.9%). The majority of individuals in both samples were found in the middle two age groups, although the church cemeteries had more in the OMA group (31.4%) compared to the monastic sample (27.4%), with the situation reversed for the YMA group: church = 27.1%, monastic = 30.4%. The church sample, therefore, had a greater proportion of individuals in the oldest two age categories (57.4%) than did the monastic sample (51.4%; see Table 6.4:5 and Figure 6.4:1).

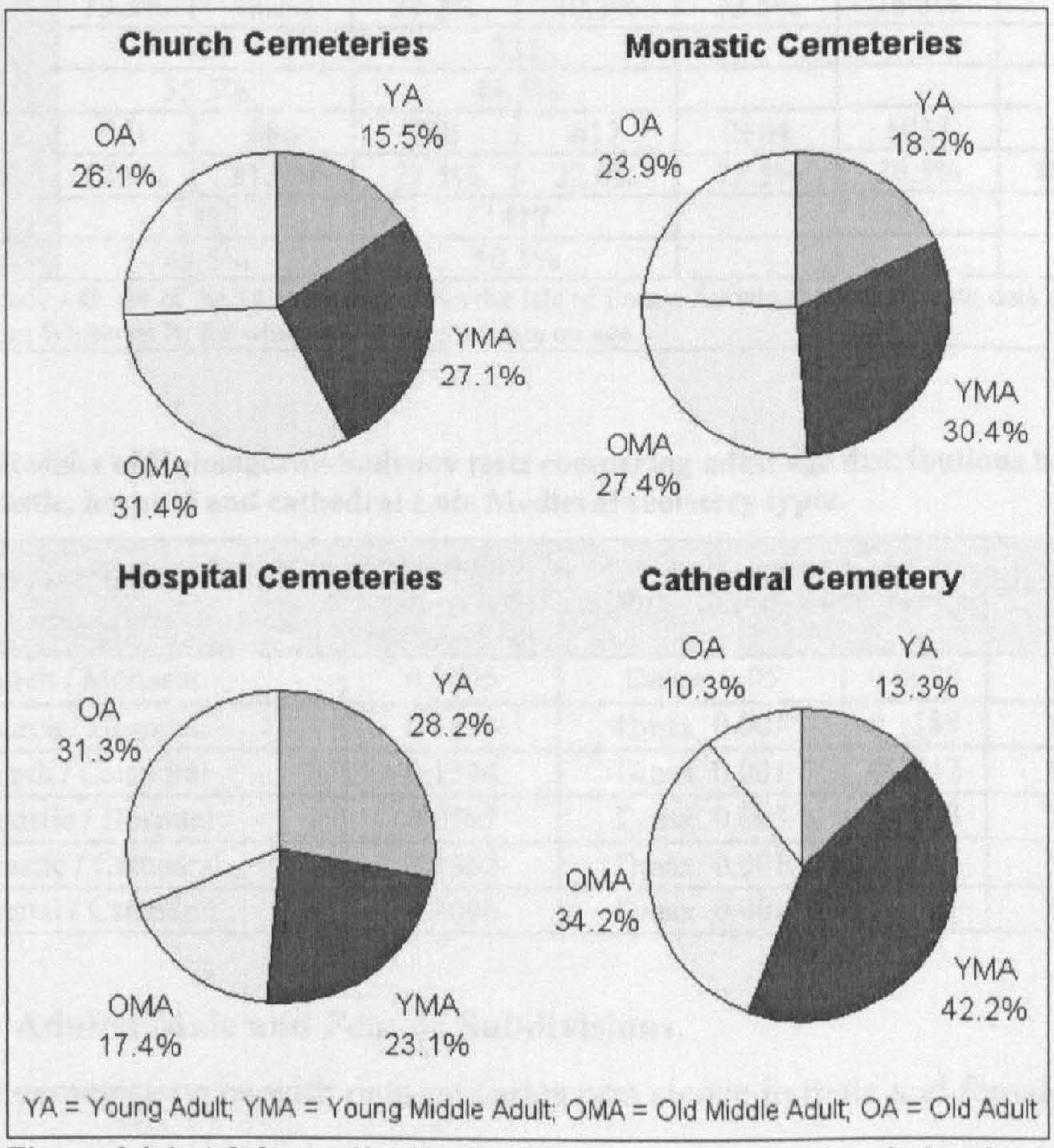


Figure 6.4:1 Adult age distribution in church, monastic, hospital and cathedral Late Medieval cemetery types.

Table 6.4:5 Number and percentage of adults in different age categories in church, monastic, hospital and cathedral Late Medieval cemetery types.

Late Medieval Cemetery Types	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Church	102	179	207	172	660	332	992
	15.5%	27.1%	31.4%	26.1%	66.5%	33.5%	❶
	281		379				100%
	42.6%		57.4%				
Monastic	172	287	259	226	944	326	1270
	18.2%	30.4%	27.4%	23.9%	74.3%	25.7%	
	459		485				100%
	48.6%		51.4%				
Hospital	128	105	79	142	454	85	539
	28.2%	23.1%	17.4%	31.3%	84.2%	15.8%	
	233		221				100%
	51.3%		48.7%				
Cathedral	99	315	255	77	746	269	1015
	13.3%	42.2%	34.2%	10.3%	73.5%	26.5%	❷
	414		332				100%
	55.5%		44.5%				
Total	501	886	800	617	2804	1012	3816
	17.9%	31.6%	28.5%	22.0%	73.5%	26.5%	❶ ❷
	1387		1417				100%
	49.5%		50.5%				

These data exclude - ❶ 84 of the 146 skeletons from the Isle of Ensay, for which there were no data on age; ❷ 78 adults from Whithorn B, for which there were no data on age.

Table 6.4:6 Results of Kolmogorov-Smirnov tests comparing adult age distributions between church, monastic, hospital and cathedral Late Medieval cemetery types.

Late Medieval Cemetery Types Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Church / Monastic	0.0605	Dmax 0.05	0.0690	No
Church / Hospital	0.1274	Dmax 0.001	0.1189	**Yes**
Church / Cathedral	0.1574	Dmax 0.001	0.1042	**Yes**
Monastic / Hospital	0.0997	Dmax 0.005	0.0988	**Yes**
Monastic / Cathedral	0.1362	Dmax 0.001	0.0955	**Yes**
Hospital / Cathedral	0.2096	Dmax 0.001	0.1161	**Yes**

6.4.1.3.2 Adults: Male and Female Subdivisions.

In the three cemetery types with data on caries prevalence in male and female teeth, a higher proportion of females than males could be aged, and both sexes had higher proportions of Aged Adults than did the adults in general (compare Table 6.4:7 with Table 6.4:5). As with the adults, the hospital sample had the highest proportion of aged individuals for both males and females, the church cemeteries had the lowest, and the monastic cemeteries lay in between.

A high proportion of both males (66.7%) and females (60.4%) were found in the two older age categories in the church sample, with similar proportions of both sexes in the OA group (Male = 31.1%, Female = 28.3%). The proportions in the YA category were also similar, with 17.8% of males and 18.9% of females (see Table 6.4:7 and Figure 6.4:2). In the monastic sample, the proportions of males (55.5%) and females (51.5%) in the two older age groups were not as great as in the church sample, although in both cemetery types slightly more males were found in this group than were females. Again there were similar proportions in the YA category (Male = 16.2%, Female = 14.1%), both being lower than the equivalent church group. In the hospital sample roughly half of the individuals of both sexes were placed in the two older age groups (Male = 49.8%, Female = 52.8%). The males had a similar proportion of individuals in both YA (29.1%) and OA (31.5%) categories, whereas there was a higher percentage of females in the OA group (35.4%) and a lower percentage in the YA group (21.5%). For none of these cemetery types was there a significant difference between the age distributions of the sexes (see Table 6.4:8).

Table 6.4:7 Number and percentage of males and females in church, monastic and hospital Late Medieval cemetery types.

Late Medieval Cemetery Type		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Church	Male	8	7	16	14	45	12	57
		17.8%	15.6%	35.6%	31.1%	78.9%	21.1%	
		15		30				100%
		33.3%		66.7%				
	Female	10	11	17	15	53	13	66
		18.9%	20.8%	32.1%	28.3%	80.3%	19.7%	
		21		32				100%
		39.6%		60.4%				
Monastic	Male	86	151	162	133	532	106	638
		16.2%	28.4%	30.5%	25.0%	83.4%	16.6%	❶
		237		295				100%
		44.5%		55.5%				
	Female	38	93	69	70	270	51	321
		14.1%	34.4%	25.6%	25.9%	84.1%	15.9%	❷
		131		139				100%
		48.5%		51.5%				
Hospital	Male	73	53	46	79	251	23	274
		29.1%	21.1%	18.3%	31.5%	91.6%	8.4%	
		126		125				100%
		50.2%		49.8%				
	Female	31	37	25	51	144	7	151
		21.5%	25.7%	17.4%	35.4%	95.4%	4.6%	
		68		76				100%
		47.2%		52.8%				
Totals	Male	167	211	224	226	828	141	969
		20.2%	25.5%	27.1%	27.3%	85.4%	14.6%	❶
		378		450				100%
		45.7%		54.3%				
	Female	79	141	111	136	467	71	538
		16.9%	30.2%	23.8%	29.1%	86.8%	13.2%	❷
		220		247				100%
		47.1%		52.9%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and ❷ 52 females from Blackfriars, Carlisle, as details of age distribution were not provided.

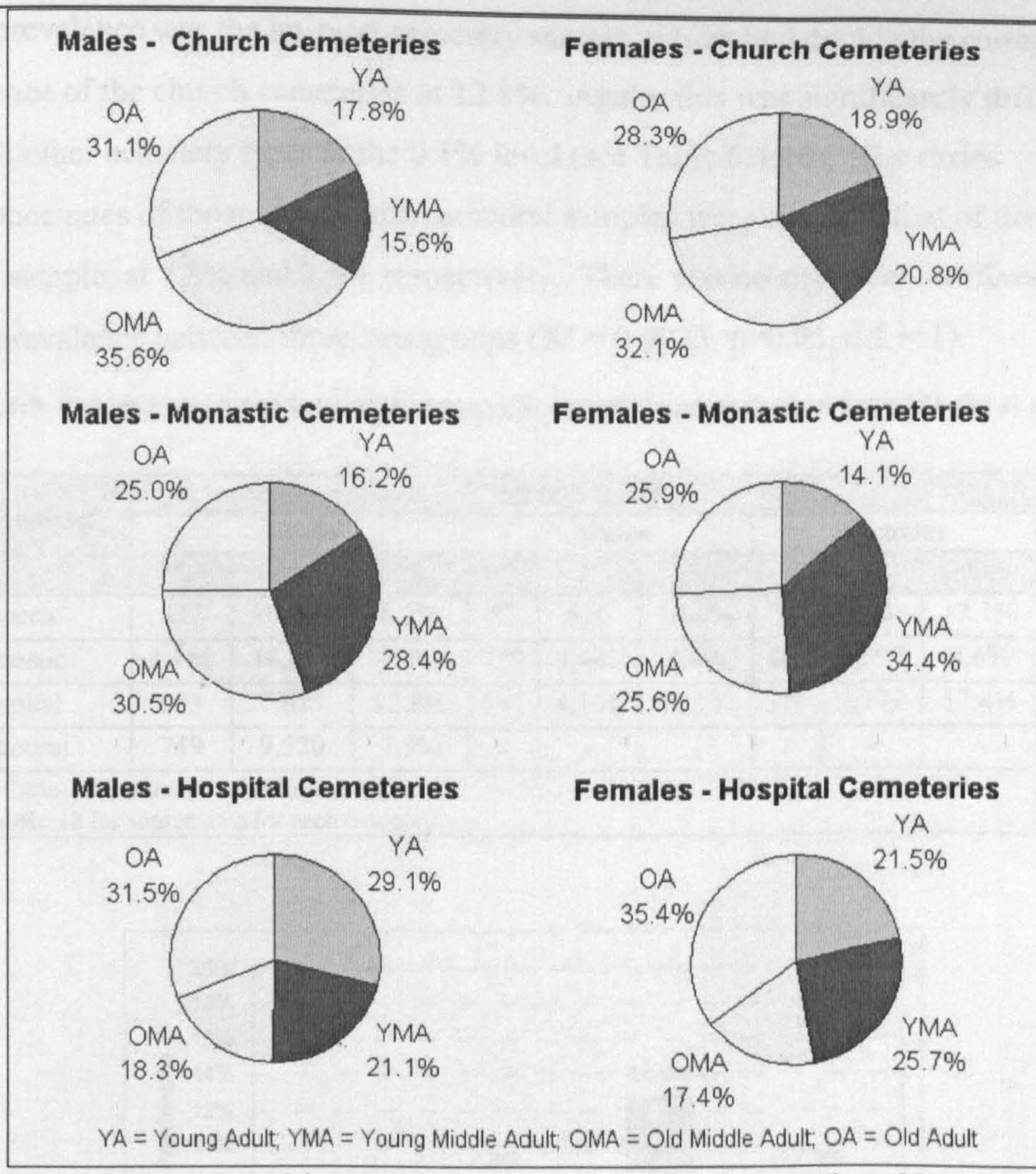


Figure 6.4:2 Male and female age distributions in church, monastic and hospital Late Medieval cemetery types.

Table 6.4:8 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within church, monastic and hospital Late Medieval cemetery types.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Church	0.0629	Dmax 0.05	0.2757	No
Monastic	0.0397	Dmax 0.05	0.1016	No
Hospital	0.0756	Dmax 0.05	0.1422	No

6.4.1.4 Caries Prevalence.

6.4.1.4.1 Teeth from Adults.

The cemetery type with the lowest caries prevalence in teeth from adults was the church cemetery sample, with a prevalence rate of 6.2% (see Table 6.4:9 and Figure 6.4:3). This was significantly different from the caries prevalence observed in all other cemetery types at the 0.1% level (see Table 6.4:10). The group with the highest caries prevalence was the hospital cemetery sample, which had double the caries prevalence of the church cemeteries at 12.8%. Again, this was significantly different from all other cemetery types at the 0.1% level (see Table 6.4:10). The caries prevalence rates of the monastic and cathedral samples were closer to that of the church sample, at 7.8% and 7.9% respectively. There was no significant difference in caries prevalence between these two groups ($X^2 = 0.0025$, $p>0.05$, d.f. = 1).

Table 6.4:9 Caries prevalence in church, monastic, hospital and cathedral Late Medieval cemetery types.

Late Medieval Cemetry Types	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Church	677	10,969	6.2%	87	616	14.1%	77	635	12.1%
Monastic	1,168	14,879	7.8%	729	9,405	7.8%	405	4,697	8.6%
Hospital	983	7,675	12.8%	541	4,141	13.1%	379	2,177	17.4%
Cathedral	749	9,520	7.9%	-	-	-	-	-	-

C = With Caries; P = Number of teeth present.
See **Appendix 10** for source data for each category.

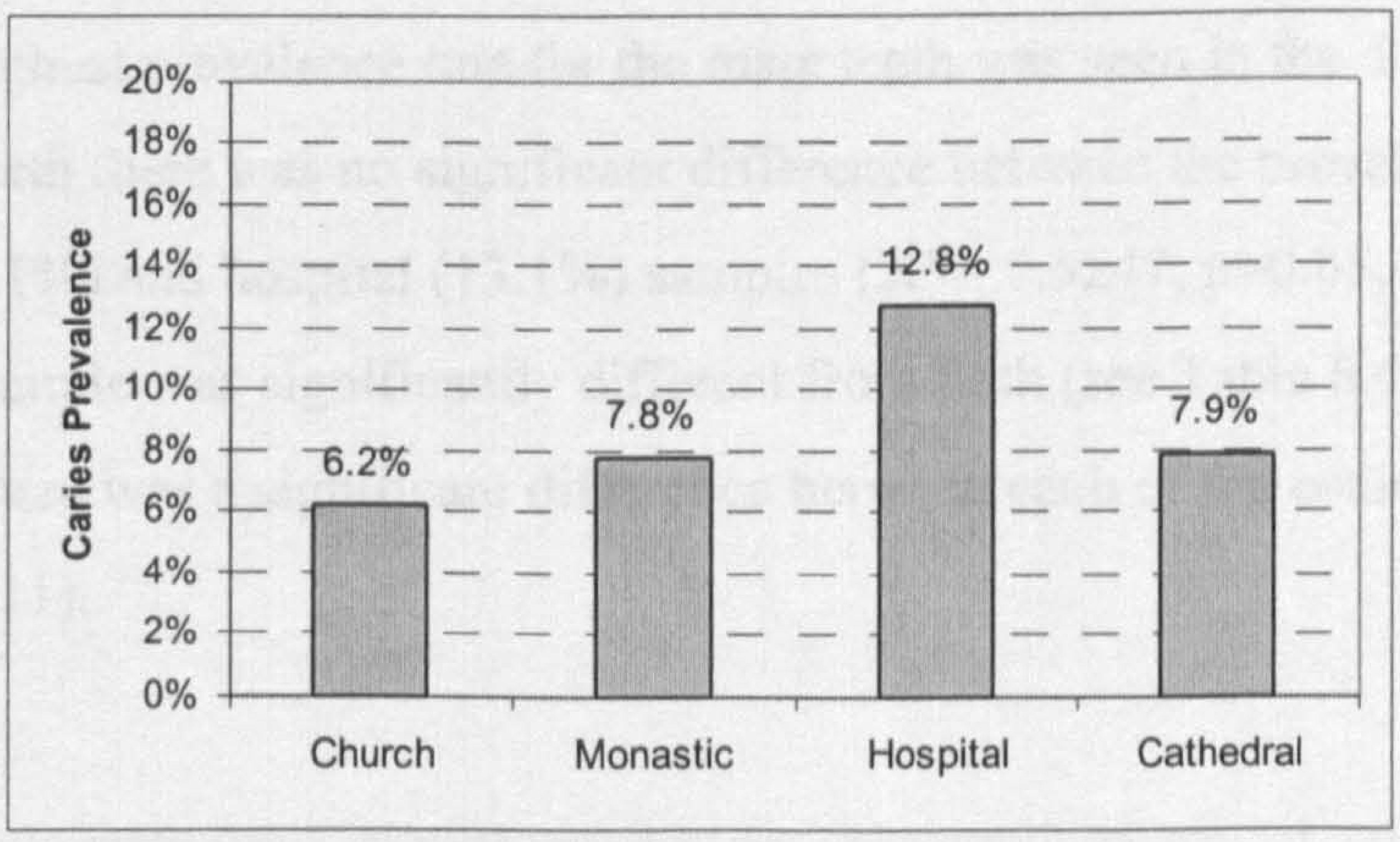


Figure 6.4:3 Caries prevalence in adult teeth in church, monastic, hospital and cathedral Late Medieval cemetery types.

Table 6.4:10 Results of chi-square test comparing caries prevalence (adult teeth) in pairs of church, monastic, hospital and cathedral Late Medieval cemetery types.

Late Medieval Cemetery Types Compared		X^2	d.f.	Significant	p
Church	Monastic	26.8235	1	Yes	p<0.001
Church	Hospital	245.1508	1	Yes	p<0.001
Church	Cathedral	22.6316	1	Yes	p<0.001
Monastic	Hospital	144.2528	1	Yes	p<0.001
Monastic	Cathedral	0.0025	1	No	p>0.05
Hospital	Cathedral	114.4879	1	Yes	p<0.001

d.f. = degrees of freedom.

6.4.1.4.2 Teeth from Adult Male and Female Subdivisions.

In two of the cemetery types, monastic and hospital, a higher caries prevalence rate was observed in the female teeth than the male teeth, but the male teeth displayed a higher prevalence in the church sample (see Table 6.4:9 and Figure 6.4:4). However, the difference between the prevalence rates for teeth from both sexes within each sample was not significant for the monastic ($X^2 = 3.2162$, $p>0.05$, d.f. = 1) or church ($X^2 = 1.0951$, $p>0.05$, d.f. = 1) samples. It was only in the hospital sample that the difference in prevalence rate between the teeth from both sexes was significant ($X^2 = 21.6502$, $p<0.001$, d.f. = 1).

For teeth from both sexes, the lowest caries prevalence rate was observed in the monastic sample (Male = 7.8%, Female = 8.6%). This is different from the results for adult teeth, where it was the church sample that had the lowest caries prevalence (6.2%). Likewise, although the highest caries prevalence for the female teeth (17.4%) was found in the hospital sample, as was the highest prevalence for adult teeth (12.8%), the highest prevalence rate for the male teeth was seen in the church sample. For the male teeth there was no significant difference between the prevalence rate for the church (14.1%) and hospital (13.1%) samples ($X^2 = 0.5247$, $p>0.05$, d.f. = 1), but the monastic sample was significantly different from both (see Table 6.4:11). For the female teeth, there was a significant difference between each of the cemetery types (see Table 6.4:11).

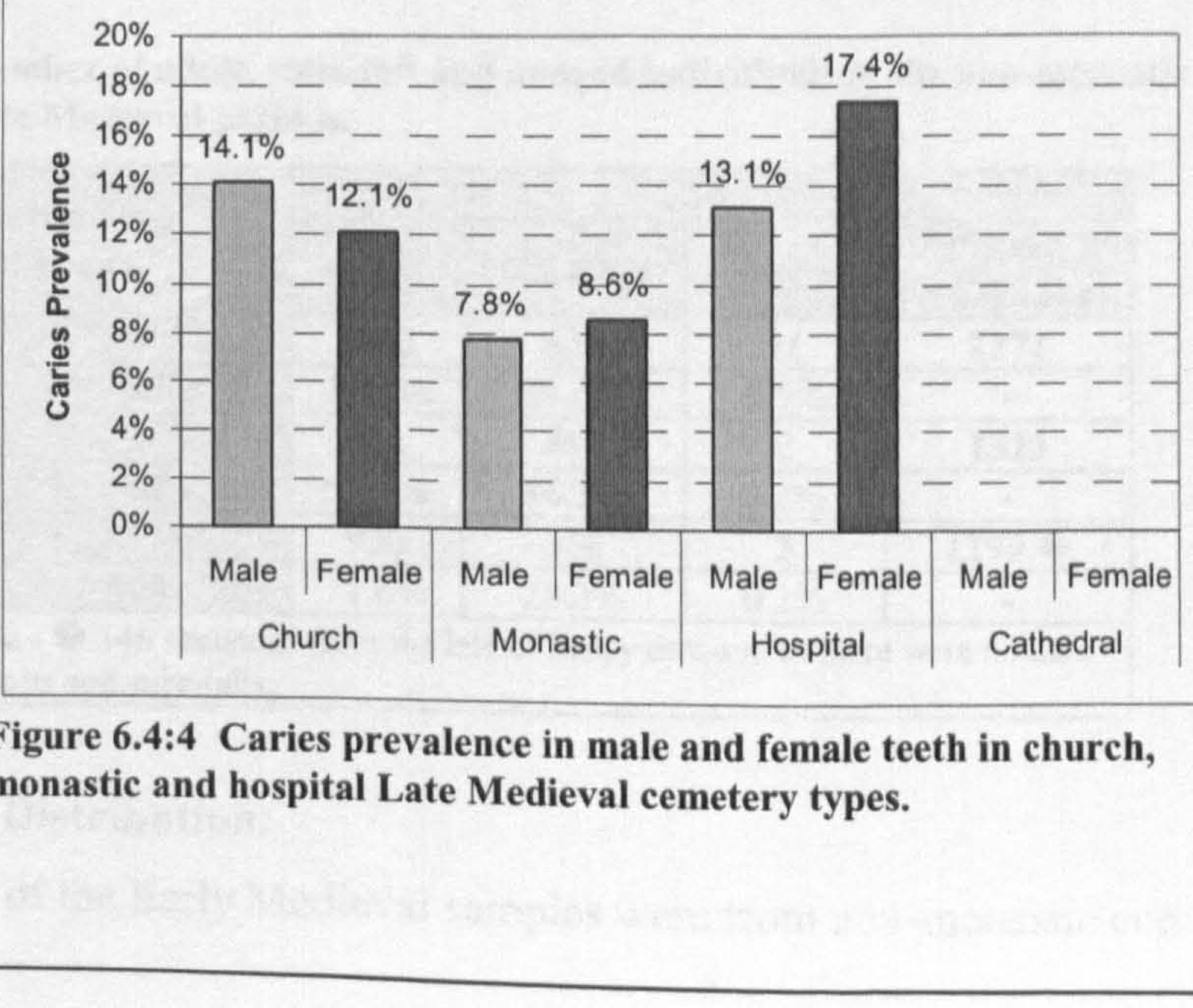


Figure 6.4:4 Caries prevalence in male and female teeth in church, monastic and hospital Late Medieval cemetery types.

Table 6.4:11 Comparison of caries prevalence in male and female teeth between pairs of church, monastic and hospital Late Medieval cemetery types: chi-square values and significance level.

Late Medieval Cemetery Types Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Church	Monastic	31.3843	1	$p<0.001$	8.3501	1	$p<0.005$
Church	Hospital	0.5247	1	$p>0.05$	10.0999	1	$p<0.005$
Monastic	Hospital	95.5301	1	$p<0.001$	113.6612	1	$p<0.001$

d.f. = degrees of freedom.

6.5 Non-Monastic and Monastic Sites: Early Medieval; Middle Medieval; Late Medieval.

6.5.1 Non-Monastic Sites.

6.5.1.1 Proportions of Adults and Subadults.

For the non-monastic sites, the largest sample of individuals came from the Early Medieval period (2272 see Table 6.5:1), which is a high proportion (91%) of the total Early Medieval sample (2495 see Table 6.3:1). A similarly high proportion (97%) of the Middle Medieval sample (1323 see Table 6.5:1) was found in the non-monastic sites. In comparison, although the Middle and Late Medieval non-monastic sites were represented by a similar number of skeletons, the Late Medieval church cemetery sample (1299 + 146 skeletons from the Isle of Ensay = 1445) was only 27% of the total Late Medieval sample. The Early and Late Medieval periods both had slightly more than 70% adults and just under 30% subadults, but the Middle Medieval sample had a smaller proportion of adults (63.6%) and a higher proportion of subadults (36.3%; see Table 6.5:1).

Table 6.5:1 Number of adult, subadult and unaged individuals in the non-monastic sites - Early, Middle and Late Medieval periods.

Non-Monastic Sites Medieval Period		Age			Total Skeletons
		Adult	Subadult	Unaged	
Early		**1602**	**659**	**11**	**2272**
	%Total	70.5%	29.0%	0.5%	-
Middle		**841**	**480**	**2**	**1323**
	%Total	63.6%	36.3%	0.2%	-
Late		**930**	**366**	**3**	**1299 ❶**
	%Total	71.6%	28.2%	0.2%	-

These data exclude - ❶ 146 skeletons from the Isle of Ensay data-set, as there were no data for numbers of adults and subadults.

6.5.1.2 Sex Distribution.

The majority of the Early Medieval samples were from non-monastic contexts, and this is reflected in the large number of skeletons available for this period. In contrast, only four data-sets were available for the Late Medieval church cemeteries, resulting in a much smaller sample size (see Table 6.5:2). Neither the Early nor Late Medieval non-monastic samples had a sex ratio that was significantly different from that expected, in contrast to the Middle Medieval sample, which did (see Table 6.5:3). There was no significant difference between the Late Medieval sample and both the Early and Middle Medieval samples in terms of proportions of males and females, but the Middle Medieval sample was significantly different (at the 5% level) from the Early Medieval sample (see Table 6.5:4).

Table 6.5:2 Number and percentage of males, females and unsexed adults in the non-monastic sites - Early, Middle and Late Medieval periods.

Non-Monastic Sites Medieval Period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Early		568	572	217	1140	1357
	%Total Adults	41.9%	42.2%	16.0%	84.0%	-
	%Sexed Adults	49.8%	50.2%	-	-	-
Middle		308	250	41	558	599
	%Total Adults	51.4%	41.7%	6.8%	93.2%	-
	%Sexed Adults	55.2%	44.8%	-	-	-
Late		57	66	30	123	153
	%Total Adults	37.3%	43.1%	19.6%	80.4%	-
	%Sexed Adults	46.3%	53.7%	-	-	-

Table 6.5:3 Results of chi-square test comparing the proportions of males and females against an expected equal distribution in the non-monastic sites - Early, Middle and Late Medieval periods.

Medieval Period		M	F	T	X^2	d.f.	Significant	p
Early	O	568	572	1140	0.0140	1	No	p>0.05
	E	570	570					
Middle	O	308	250	558	6.0287	1	Yes	p<0.025
	E	279	279					
Late	O	57	66	123	0.6585	1	No	p>0.05
	E	61.5	61.5					

d.f. = degrees of freedom; **O** = Observed value; **E** = Expected value.

Table 6.5:4 Results of chi-square test comparing the proportions of males and females in the non-monastic sites in pairs of periods - Early, Middle and Late Medieval periods.

Medieval Periods Compared		X^2	d.f.	Significant	p
Early	Middle	4.3298	1	Yes	p<0.05
Early	Late	0.5388	1	No	p>0.05
Middle	Late	3.1780	1	No	p>0.05

d.f. = degrees of freedom.

6.5.1.3 Age Distribution.

6.5.1.3.1 Adults in General.

Both Early and Middle Medieval non-monastic samples had a greater proportion of Aged Adults than did the Late Medieval church sample (see Table 6.5:5). The non-monastic sample for each main period was significantly different from both other samples (see Table 6.5:6). In the Early Medieval sample, the adults were fairly evenly divided into the four age categories, with most being found in the youngest two categories (53.6%). In the Middle Medieval sample, only 15.7% of the individuals were found in the OA category, with the remaining adults distributed fairly equally between the remaining three categories. Again, most individuals were found in the youngest two age categories (54.8%). The Late Medieval church sample contrasts with the earlier periods, in that only 42.6% of the individuals were placed in the two youngest age categories, and the category with the fewest individuals was the YA group (15.5%; see Table 6.5:5 and Figure 6.5:1).

Whereas the YMA category had similar proportions of individuals for all three periods (Early Medieval = 27.3%, Middle Medieval = 28.0%, Late Medieval = 27.1%), and the YA category had similar proportions for both the Early and Middle Medieval samples (Early Medieval = 26.4%, Middle Medieval = 26.8%), the Late Medieval sample only had 15.5% of its adults in this group (see Table 6.5:5 and Figure 6.5:1). With the OA category, the proportions in the Early and Late Medieval periods were similar (24.5% and 26.1% respectively), but the Middle Medieval sample only had 15.7% of its individuals in this category. The OMA group, on the other hand, was similar between the Middle (29.6%) and Late (21.4%)Medieval periods, but the Early Medieval sample had proportionally fewer individuals in this group at 21.9%.

Table 6.5:5 Number and percentage of adults in different age categories in the non-monastic sites - Early, Middle and Late Medieval periods.

Non-Monastic Sites	Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Early Medieval	320	331	266	297	1214	388	1602
	26.4%	27.3%	21.9%	24.5%	75.8%	24.2%	
	651		563				100%
	53.6%		46.4%				
Middle Medieval	135	141	149	79	504	135	639
	26.8%	28.0%	29.6%	15.7%	78.9%	21.1%	❶
	276		228				100%
	54.8%		45.2%				
Late Medieval	102	179	207	172	660	332	992
	15.5%	27.1%	31.4%	26.1%	66.5%	33.5%	❷
	281		379				100%
	42.6%		57.4%				
Total	557	651	622	548	2378	855	3233
	23.4%	27.4%	26.2%	23.0%	73.6%	26.4%	❶ ❷
	1208		1170				100%
	50.8%		49.2%				

These data exclude - ❶ 202 adults from Trowbridge, as they are only placed in two broad categories; ❷ 84 of the 146 skeletons from the Isle of Ensay, for which there were no data on age.

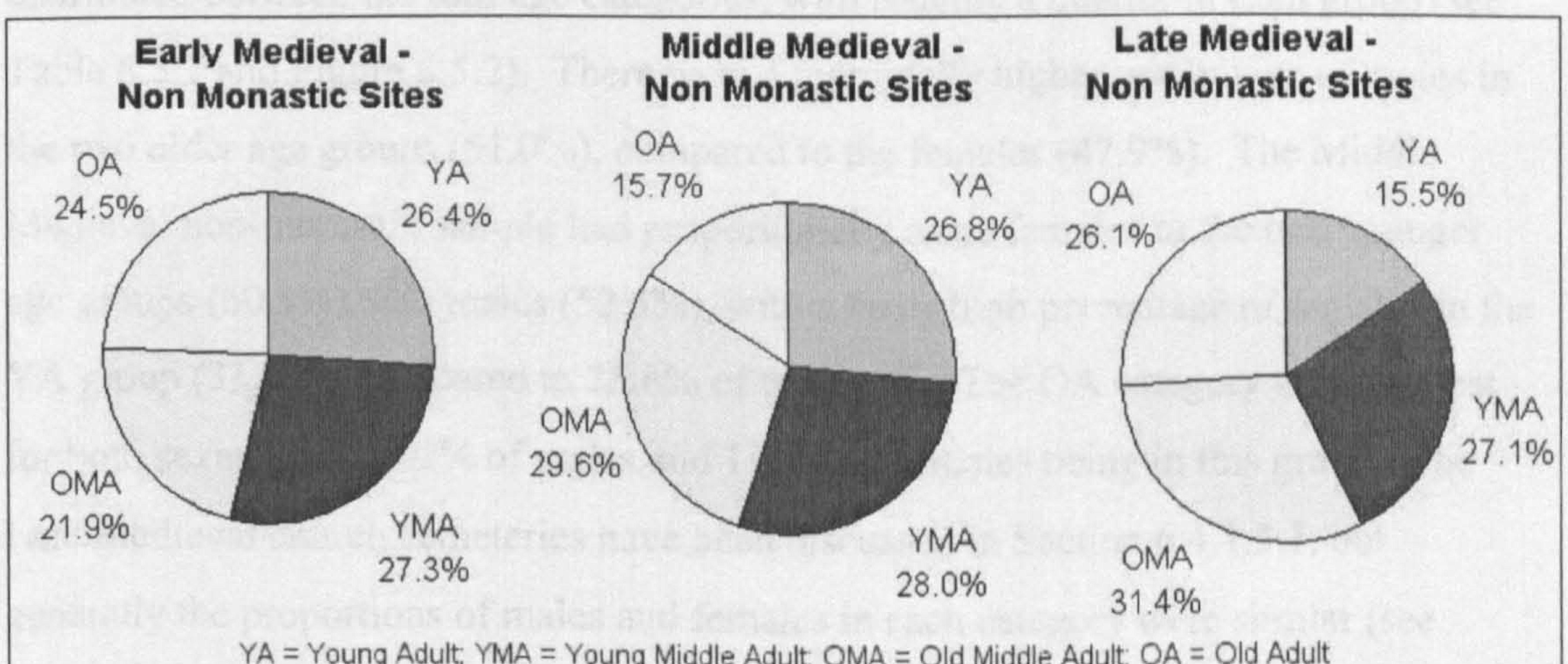


Figure 6.5:1 Adult age distribution in the non-monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:6 Results of Kolmogorov-Smirnov tests comparing adult age distributions between the non-monastic sites - Early, Middle and Late Medieval periods.

Non-Monastic Sites Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early / Middle	0.0879	Dmax 0.01	0.0864	**Yes**
Early / Late	0.1105	Dmax 0.001	0.0943	**Yes**
Middle / Late	0.1219	Dmax 0.001	0.1154	**Yes**

6.5.1.3.2 Adults: Male and Female Subdivisions.

Similar proportions of the males and females had been aged in all three Medieval samples (see Table 6.5:7). In the Early Medieval sample a higher proportion of females had been aged (83.9%) compared to males (80.5%), but the position was reversed for the Middle Medieval sample (Male = 83.8%, Female = 80.0%). In comparison, 80.3% of the Late Medieval females and 78.9% of the males had been aged. The proportion of Aged Adults for both sexes was higher than the proportion of Aged Adults in general for all three periods (compare Table 6.5:7 with Table 6.5:5).

Both males and females in the Early Medieval non-monastic sample were fairly evenly distributed between the four age categories, with roughly a quarter in each group (see Table 6.5:7 and Figure 6.5:2). There were a marginally higher percentage of males in the two older age groups (51.0%), compared to the females (47.9%). The Middle Medieval non-monastic sample had proportionally more females in the two younger age groups (60.5%) than males (52.3%), with a fairly high percentage of females in the YA group (31.0%), compared to 25.6% of the males. The OA category was smallest for both sexes, with 18.2% of males and 11.5% of females being in this group. The Late Medieval church cemeteries have been discussed in Section 6.4.1.3.1, but generally the proportions of males and females in each category were similar (see Table 6.5:7 and Figure 6.5:2). Compared to the two earlier periods, there were more individuals, males (66.7%) and females (60.4%), in the two older age categories, and fewer in the YA group (Male = 17.8%, Female = 18.9%). There were no significant differences between the age distributions of the males and females in the non-monastic sites for any of the periods (see Table 6.5:8).

Table 6.5:7 **Number and percentage of males and females in each age category in the non-monastic sites - Early, Middle and Late Medieval periods.**

Non-Monastic Sites by period		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early Medieval	Male	99	125	119	114	457	111	568
		21.7%	27.4%	26.0%	24.9%	80.5%	19.5%	
		224		233				100%
		49.0%		51.0%				
	Female	128	122	103	127	480	92	572
		26.7%	25.4%	21.5%	26.5%	83.9%	16.1%	
		250		230				100%
		52.1%		47.9%				
Middle Medieval	Male	66	69	76	47	258	50	308
		25.6%	26.7%	29.5%	18.2%	83.8%	16.2%	
		135		123				100%
		52.3%		47.7%				
	Female	62	59	56	23	200	50	250
		31.0%	29.5%	28.0%	11.5%	80.0%	20.0%	
		121		79				100%
		60.5%		39.5%				
Late Medieval	Male	8	7	16	14	45	12	57
		17.8%	15.6%	35.6%	31.1%	78.9%	21.1%	
		15		30				100%
		33.3%		66.7%				
	Female	10	11	17	15	53	13	66
		18.9%	20.8%	32.1%	28.3%	80.3%	19.7%	
		21		32				100%
		39.6%		60.4%				
Totals	Male	173	201	211	175	760	173	933
		22.8%	26.4%	27.8%	23.0%	81.5%	18.5%	
		374		386				100%
		49.2%		50.8%				
	Female	200	192	176	165	733	155	888
		27.3%	26.2%	24.0%	22.5%	82.5%	17.5%	
		392		341				100%
		53.5%		46.5%				

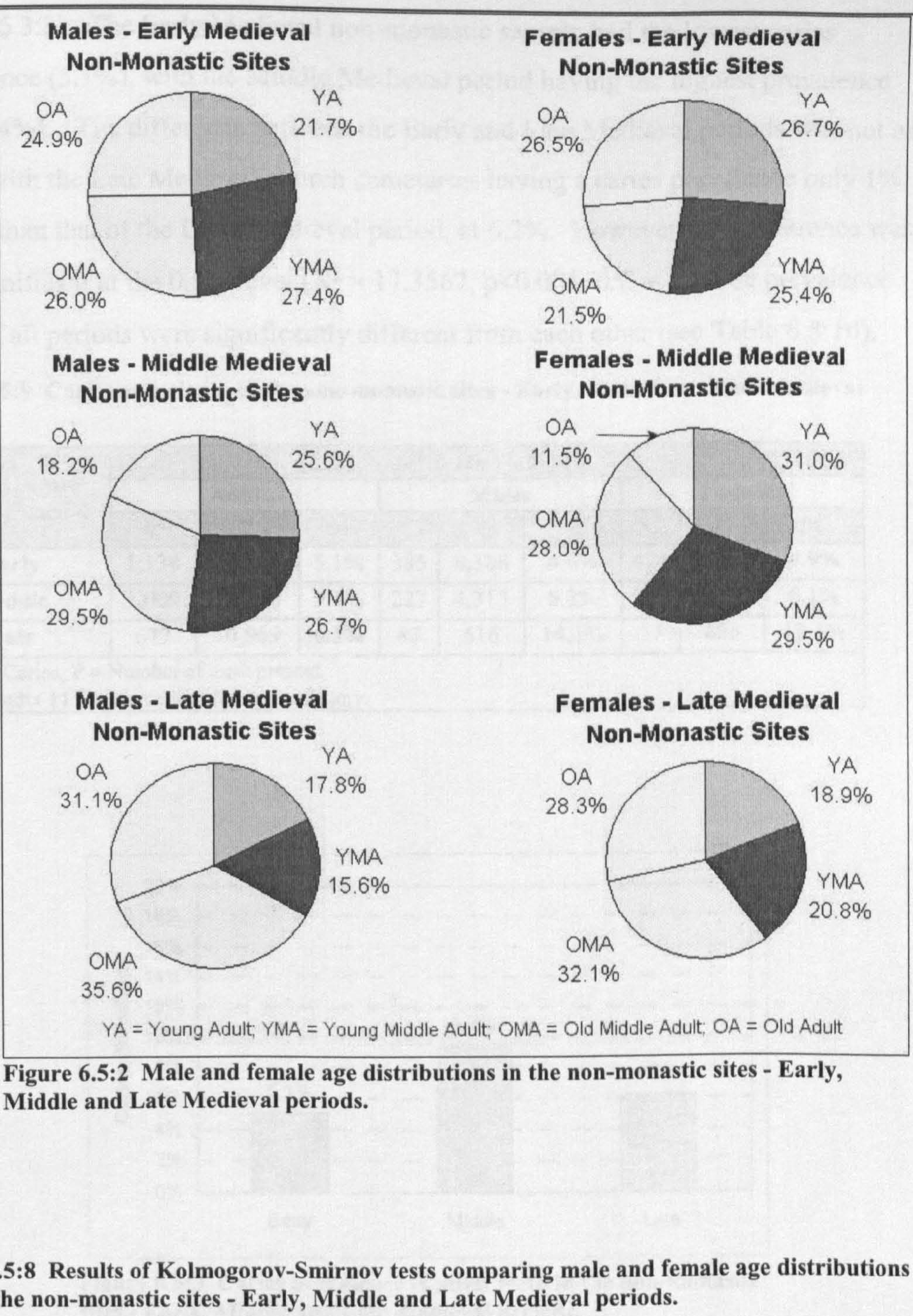


Figure 6.5:2 Male and female age distributions in the non-monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:8 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within the non-monastic sites - Early, Middle and Late Medieval periods.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early Medieval	0.0500	Dmax 0.05	0.0889	No
Middle Medieval	0.0817	Dmax 0.05	0.1281	No
Late Medieval	0.0629	Dmax 0.05	0.2757	No

6.5.1.4 Caries Prevalence.

6.5.1.4.1 Teeth from Adults.

A similar pattern to that seen in the total samples for each of the three Main Periods was observed in the non-monastic sites (compare Table 6.5:9 and Figure 6.5:3 with

Figure 6.3:3). The Early Medieval non-monastic sample had the lowest caries prevalence (5.1%), with the Middle Medieval period having the highest prevalence rate (9.4%). The difference between the Early and Late Medieval periods was not as great, with the Late Medieval church cemeteries having a caries prevalence only 1% higher than that of the Early Medieval period, at 6.2%. However, this difference was still significant at the 0.1% level ($X^2 = 17.3567$, $p<0.001$, d.f. = 1). The prevalence rates of all periods were significantly different from each other (see Table 6.5:10).

Table 6.5:9 Caries prevalence in the non-monastic sites - Early, Middle and Late Medieval periods.

Non-Monastic Sites by period	Teeth from Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Early	1,134	22,362	5.1%	385	8,388	4.6%	424	8,695	4.9%
Middle	1,009	10,756	9.4%	227	4,315	5.3%	205	3,356	6.1%
Late	677	10,969	6.2%	87	616	14.1%	77	635	12.1%

C = With Caries; P = Number of teeth present.
See **Appendix 11** for source data for each category.

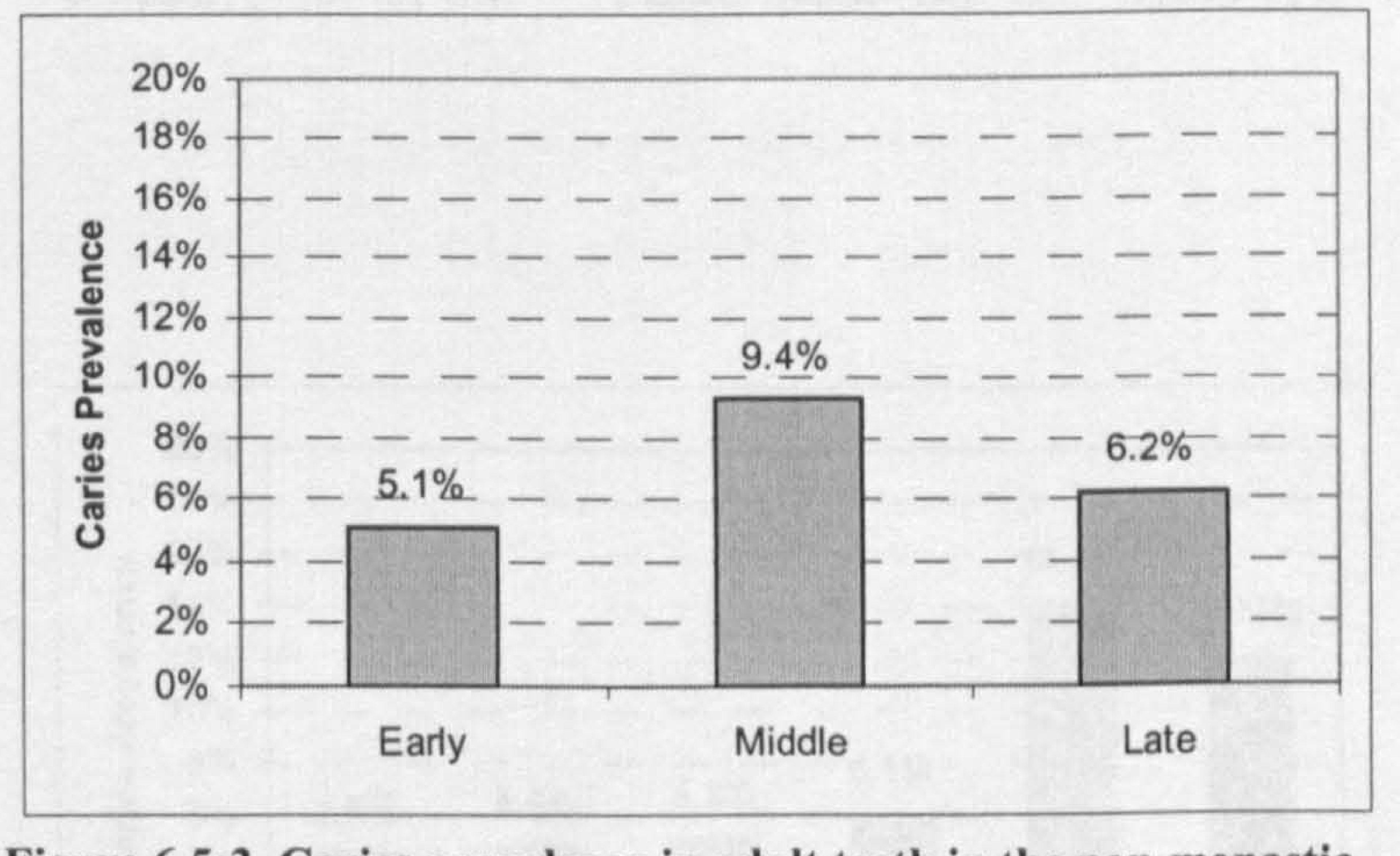


Figure 6.5:3 Caries prevalence in adult teeth in the non-monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:10 Results of chi-square test comparing caries prevalence (adult teeth) in the non-monastic sites in pairs of periods - Early, Middle and Late Medieval periods.

Medieval Periods Compared		X^2	d.f.	Significant	p
Early	Middle	222.8885	1	Yes	p<0.001
Early	Late	17.3567	1	Yes	p<0.001
Middle	Late	78.1176	1	Yes	p<0.001

d.f. = degrees of freedom.

6.5.1.4.2 Teeth from Adult Male and Female Subdivisions.

Again, a similar pattern was seen in the caries prevalence in the male and female teeth from the non-monastic sites (see Table 6.5:9 and Figure 6.5:4) to that occurring in the male and female teeth for the three Main Periods (see Table 6.3:7 and Figure 6.3:4). The lowest caries prevalence in teeth from both sexes was seen in the Early Medieval non-monastic sites (Male = 4.6%, Female = 4.9%), with a slightly higher prevalence in the Middle Medieval non-monastic sample (Male = 5.3%, Female = 6.1%). This difference was not significant for the male teeth ($X^2 = 2.7961$, $p>0.05$, d.f. = 1) but was significant for the female teeth ($X^2 = 7.4304$, $p<0.01$, d.f. = 1). The Late Medieval church cemeteries had the highest caries prevalence (Male = 14.1%, Female = 12.1%), which was significantly different from the caries prevalence rates in both Early and Middle Medieval periods for teeth from both sexes (see Table 6.5:11). Within each period the difference between caries prevalence rates in male and female teeth was not significant (Early Medieval: $X^2 = 0.7766$, $p>0.05$, d.f. = 1; Middle Medieval: $X^2 = 2.5528$, $p>0.05$, d.f. = 1; Late Medieval: $X^2 = 1.0951$, $p>0.05$, d.f. = 1).

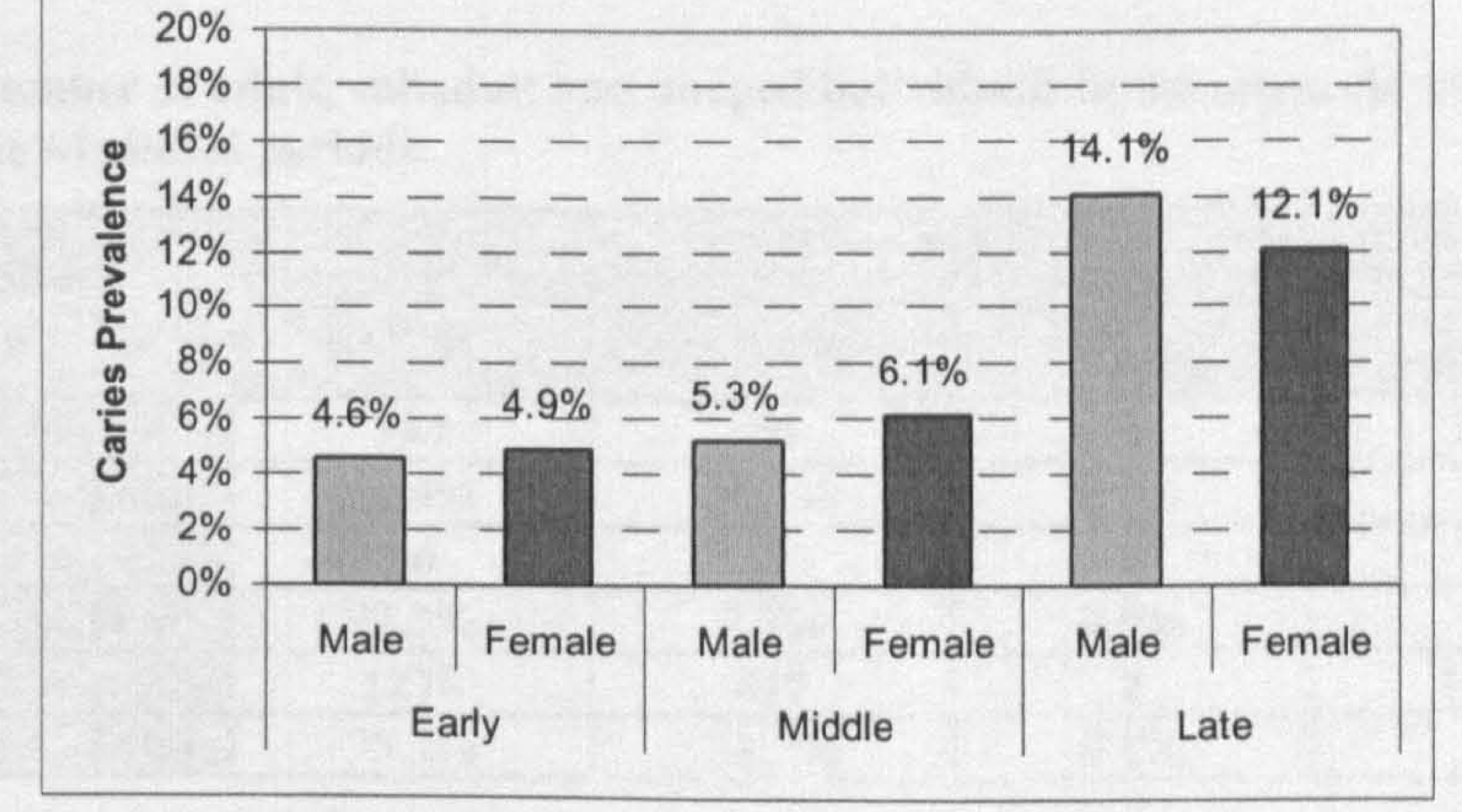


Figure 6.5:4 Caries prevalence in male and female teeth in the non-monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:11 Comparison of caries prevalence in male and female teeth between pairs of non-monastic samples - Early, Middle and Late Medieval periods: chi-square values and significance level.

Medieval Periods Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	P
Early	Middle	2.7961	1	p>0.05	7.4304	1	p<0.01
Early	Late	104.999	1	p<0.001	61.2077	1	p<0.001
Middle	Late	71.0125	1	p<0.001	29.4447	1	p<0.001

d.f. = degrees of freedom.

6.5.2 Monastic sites.

6.5.2.1 Proportions of Adults and Subadults.

In contrast to the non-monastic sites discussed above, the Late Medieval period had the largest sample size for the monastic sites (see Table 6.5:12). The number of individuals from Late Medieval monastic sites (1689) made up 31% of the total Late Medieval sample (5410 including 146 skeletons from the Isle of Ensay see Table 6.3:1). In comparison, the number of individuals from the Early Medieval monastic sites was 9% of the total Early Medieval sample, and the Middle Medieval monastic sample was only 3% of the original Middle Medieval sample. The proportion of adults and subadults was different in all three periods (see Table 6.5:12). The Middle Medieval sample had the highest proportion of adults (92.3%), followed by the Late Medieval sample (75.2%). The Early Medieval sample had the smallest proportion of adults, at 61.4%.

Table 6.5:12 Number of adult, subadult and unaged individuals in the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites Medieval Period		Age: Adult	Subadult	Unaged	Total Skeletons
Early		137	86	0	223
	%Total	61.4%	38.6%	0.0%	-
Middle		36	3	0	39
	%Total	92.3%	7.7%	0.0%	-
Late		1270	417	2	1689
	%Total	75.2%	24.7%	0.1%	-

6.5.2.2 Sex Distribution.

No monastic sites provided data for caries prevalence in teeth from males and females in the Middle Medieval period, and only one provided data for the Early Medieval period (Jarrow A, Tyne and Wear). The sample size for the Early Medieval period is therefore considerably smaller than that for the Late Medieval period, where ten sites provided data.

The proportion of males and females in the Early Medieval sample, at 56.2% and 43.8% (see Table 6.5:13), was not significantly different from the normal even division of sexes expected ($X^2 = 1.1096$, $p>0.05$, d.f. = 1). As has been discussed in Section 6.4.1.2 above, the Late Medieval monastic sites had significantly more males than females. However, there was no significant difference between the two samples in terms of proportions of each sex ($X^2 = 3.0639$, $p>0.05$, d.f. = 1).

Table 6.5:13 Number and percentage of males, females and unsexed adults in the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites Medieval Period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Early		41	32	24	73	97
	%Total Adults	42.3%	33.0%	24.7%	75.3%	-
	%Sexed Adults	56.2%	43.8%	-	-	-
Middle		-	-	-	-	-
	%Total Adults	-	-	-	-	-
	%Sexed Adults	-	-	-	-	-
Late		731	373	166	1104	1270
	%Total Adults	57.6%	29.4%	13.1%	86.9%	-
	%Sexed Adults	66.2%	33.8%	-	-	-

6.5.2.3 Age Distribution.

6.5.2.3.1 Adults in General.

A large proportion of the adults in the Early Medieval monastic sample were unaged (48.2%), meaning only slightly more than half of the adults could be placed into an age category (51.8%). The Middle Medieval and Late Medieval monastic samples fared better, with 66.7% and 74.3% of their adults being assigned an age group (see Table 6.5:14).

The Early Medieval monastic sample had considerably more individuals in the older two age categories (62.0%) than in the younger two categories, with the YA group having the smallest number of individuals (12.7%; see Table 6.5:14 and Figure 6.5:5). In contrast, the majority of the Middle Medieval adults were found in the youngest two age groups (70.8%), with the OMA group having the smallest number of individuals (8.3%). The adults in the Late Medieval monastic sample were more evenly distributed in comparison, and this has already been described in more detail above. Briefly, around half the adults were found in the two older age groups (51.4%), which was more than the Middle Medieval sample, but not as many as the Early Medieval sample, and the age category with the smallest number of individuals was the YA group (see Table 6.5:14 and Figure 6.5:5). Despite the apparent differences between the three samples in terms of age distribution, the only periods that were significantly different from each other were the Early Medieval and Middle Medieval periods (see Table 6.5:15). It is highly probable that this lack of significance is accounted for by the small sample sizes available for the Early Medieval and Middle Medieval periods in comparison to that available for the Late Medieval period.

Table 6.5:14 Number and percentage of adults in different age categories in the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early Medieval	9	18	24	20	71	66	137
	12.7%	25.4%	33.8%	28.2%	51.8%	48.2%	
	27		44				100%
	38.0%		62.0%				
Middle Medieval	8	9	2	5	24	12	36
	33.3%	37.5%	8.3%	20.8%	66.7%	33.3%	
	17		7				100%
	70.8%		29.2%				
Late Medieval	172	287	259	226	944	326	1270
	18.2%	30.4%	27.4%	23.9%	74.3%	25.7%	
	459		485				100%
	48.6%		51.4%				
Total	189	314	285	251	1039	404	1443
	18.2%	30.2%	27.4%	24.2%	72.0%	28.0%	
	503		536				100%
	48.4%		51.6%				

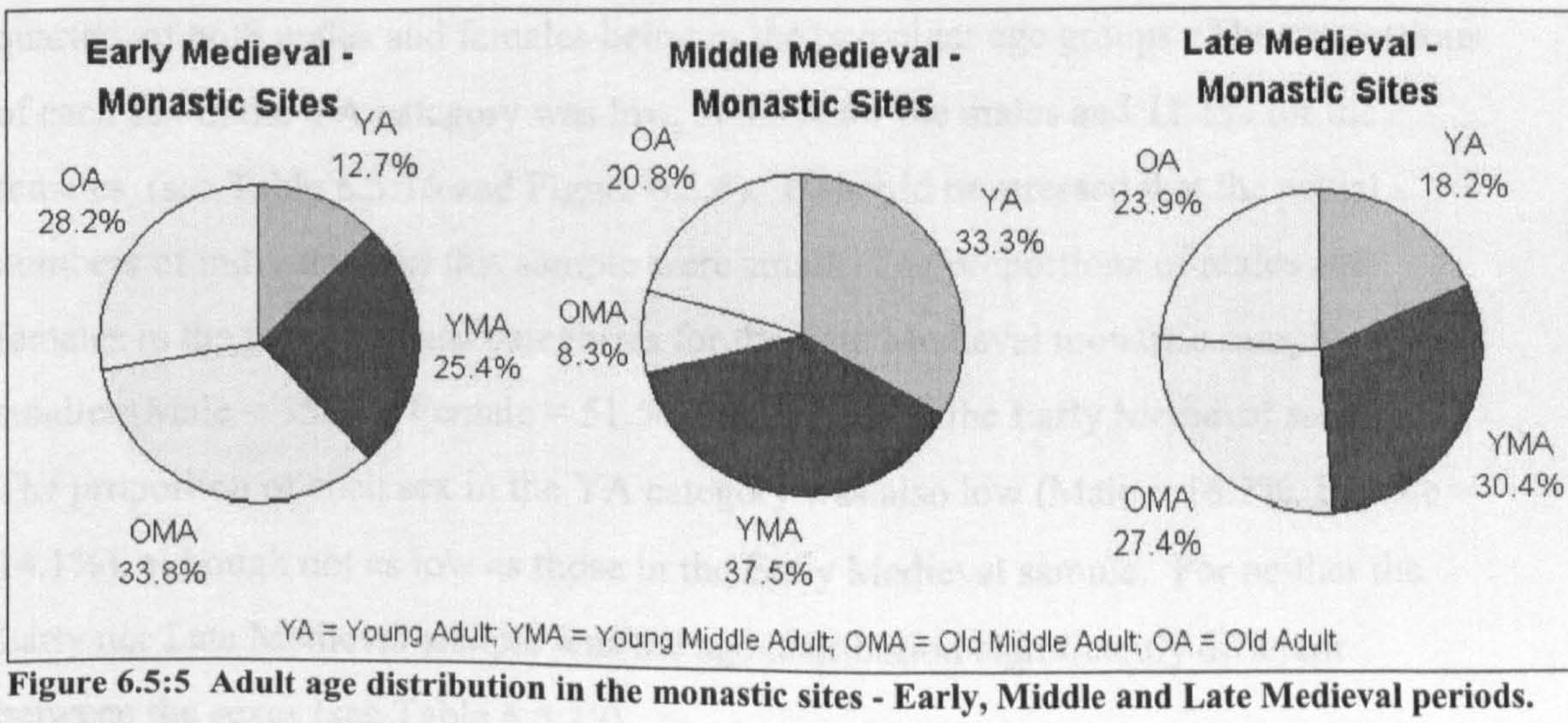


Figure 6.5:5 Adult age distribution in the monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:15 Results of Kolmogorov-Smirnov tests comparing adult age distributions between the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early / Middle	0.3281	Dmax 0.05	0.3211	**Yes**
Early / Late	0.1059	Dmax 0.05	0.1674	No
Middle / Late	0.2221	Dmax 0.05	0.2811	No

6.5.2.3.2 Adults: Male and Female Subdivisions.

There were no data available on caries prevalence in male and female teeth for the Middle Medieval period, so this section only discusses the Early and Late Medieval samples. The proportion of Aged Adults for both males and females in the Early Medieval monastic sample was low, at 53.7% and 56.3% respectively (see Table 6.5:16). This was still slightly higher than the percentage of Aged Adults in general (51.8%), and again there were a higher proportion of aged females than males. The Late Medieval monastic sample also had a higher proportion of aged females than males, and the proportion of individuals of both sexes was higher than that of the Aged Adults in general (compare Table 6.5:16 with Table 6.5:14).

In the Early Medieval sample the proportion of both males and females in the OA group was high, at 50.0% for the males and 44.4% for the females. When these were combined with the individuals in the OMA category, this resulted in nearly three-quarters of both males and females being in the two older age groups. The proportions of each sex in the YA category was low, at 4.5% for the males and 11.1% for the females (see Table 6.5:16 and Figure 6.5:6). It should be stressed that the actual numbers of individuals in this sample were small. The proportions of males and females in the two older age categories for the Late Medieval monastic sample were smaller (Male = 55.5%, Female = 51.5%) than those in the Early Medieval sample. The proportion of each sex in the YA category was also low (Male = 16.2%, Female = 14.1%), although not as low as those in the Early Medieval sample. For neither the Early nor Late Medieval sample was the age distribution significantly different between the sexes (see Table 6.5:17).

Table 6.5:16 Number and percentage of males and females in the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites by period		Aged Adults (% Total Aged): Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Early Medieval	Male	1	5	5	11	22	19	41
		4.5%	22.7%	22.7%	50.0%	53.7%	46.3%	
		6		16				100%
		27.3%		72.7%				
	Female	2	3	5	8	18	14	32
		11.1%	16.7%	27.8%	44.4%	56.3%	43.8%	
		5		13				100%
		27.8%		72.2%				
Middle Medieval	Male	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
	Female	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
Late Medieval	Male	86	151	162	133	532	106	638
		16.2%	28.4%	30.5%	25.0%	83.4%	16.6%	❶
		237		295				100%
		44.5%		55.5%				
	Female	38	93	69	70	270	51	321
		14.1%	34.4%	25.6%	25.9%	84.1%	15.9%	❷
		131		139				100%
		48.5%		51.5%				
Totals	Male	87	156	167	144	554	125	679
		15.7%	28.2%	30.1%	26.0%	81.6%	18.4%	❶
		243		311				100%
		43.9%		56.1%				
	Female	40	96	74	78	288	65	353
		13.9%	33.3%	25.7%	27.1%	81.6%	18.4%	❷
		136		152				100%
		47.2%		52.8%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and ❷ 52 females from Blackfriars, Carlisle, as details of age distribution were not provided.

Table 6.5:17 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within the monastic sites - Early and Late Medieval periods.

Male/Female Compared	Observed Maximum Difference	Dmax Significance level		Significant ?
Early Medieval	0.0657	Dmax 0.05	0.4322	No
Middle Medieval	-	-	-	-
Late Medieval	0.0397	Dmax 0.05	0.1016	No

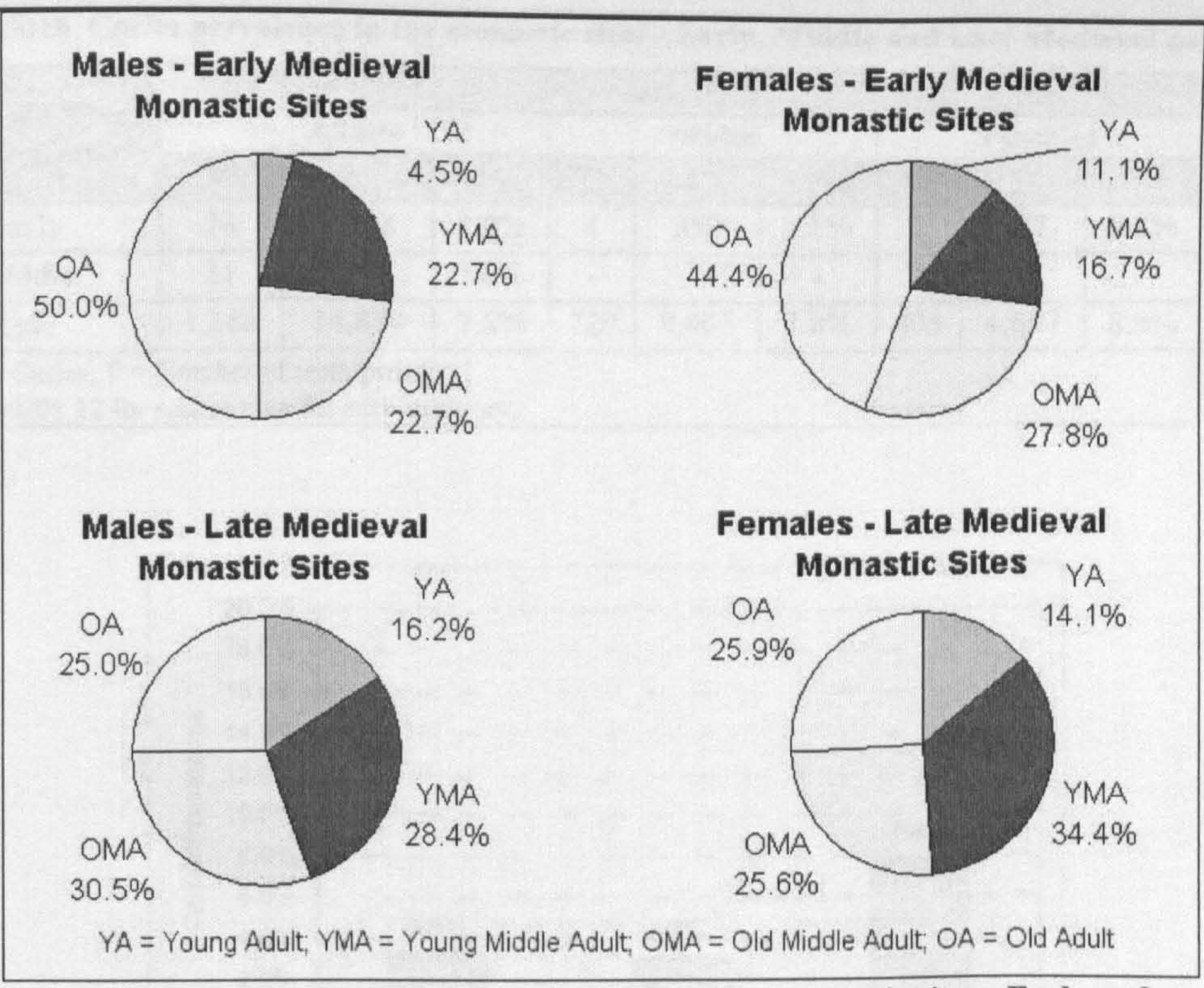


Figure 6.5:6 Male and female age distributions in the monastic sites - Early and Late Medieval periods.

6.5.2.4 Caries Prevalence.

6.5.2.4.1 Teeth from Adults.

The caries prevalence rates in adult teeth from the Early and Middle Medieval monastic samples (see Table 6.5:18 and Figure 6.5:7) were not significantly different from each other ($X^2 = 0.1540$, $p>0.05$, d.f. = 1). These rates were both lower than that observed for the non-monastic samples in each period (compare Figure 6.5:7 and Figure 6.5:3). This difference between monastic and non-monastic samples was significant for both periods (Early Medieval: $X^2 = 5.9958$, $p<0.025$, d.f. = 1; Middle Medieval: $X^2 = 17.2709$, $p<0.001$, d.f. = 1).

The caries prevalence observed in the adult teeth from the Late Medieval monastic sample was double that of the preceding periods, at 7.8%. This was significantly different from both the Early ($X^2 = 28.8902$, $p<0.001$, d.f. = 1) and Middle ($X^2 = 11.7490$, $p<0.001$, d.f. = 1) Medieval samples. In contrast to the preceding two periods, the monastic sample had higher caries prevalence than the Late Medieval church sample (6.2%, see Figure 6.4:3).

Table 6.5:18 Caries prevalence in the monastic sites - Early, Middle and Late Medieval periods.

Monastic Sites by period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Early	38	1,108	3.4%	4	352	1.1%	2	257	0.8%
Middle	11	366	3.0%	-	-	-	-	-	-
Late	1,168	14,879	7.8%	729	9,405	7.8%	405	4,697	8.6%

C = With Caries; **P** = Number of teeth present.
See **Appendix 12** for source data for each category.

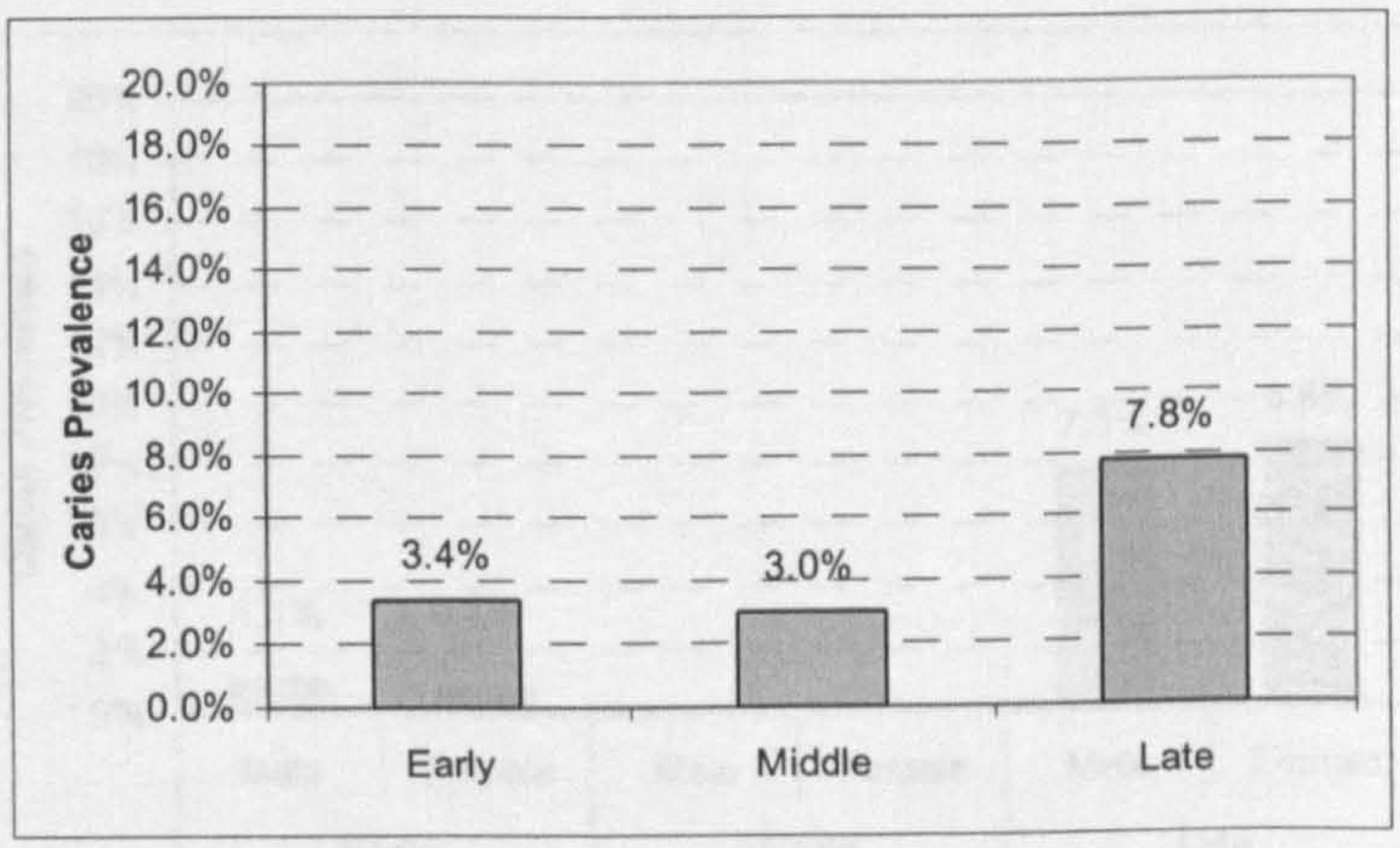


Figure 6.5:7 Caries prevalence in adult teeth in the monastic sites - Early, Middle and Late Medieval periods.

6.5.2.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence in the Early Medieval monastic sample for both male and female teeth was particularly low, with the male teeth having a prevalence of 1.1% and the female teeth a prevalence of 0.8% (see Table 6.5:18 and Figure 6.5:8). The chi-square test could not be applied to test whether these were significantly different or not, as the expected frequencies in two of the cells was below 5. As with the adult teeth, the caries prevalence in both male and female teeth was lower than that observed in the Early Medieval non-monastic sample (see Figure 6.5:4). In both cases this difference was significant (M: $X^2 = 9.4744$, $p<0.005$, d.f. = 1; F: $X^2 = 9.2501$, $p<0.005$, d.f. = 1).

The caries prevalence in the Late Medieval monastic sample for male and female teeth (7.8% and 8.6% respectively) was considerably higher than that in the Early Medieval sample (see Figure 6.5:8). In both cases the difference between Early and Late Medieval prevalence rates was significant (Table 6.5:19). As with the Early Medieval sample, there was no significant difference between the caries prevalence rates of the male and female teeth in the Late Medieval monastic sample ($X^2 = 3.2162$, $p<0.001$, d.f. = 1). The Late Medieval church and monastic sites have already been compared (see Section 6.4.1.4.1), but in summary the prevalence rates in the church sample were higher for both male and female teeth (unlike the caries prevalence in the adult teeth), and this difference was statistically significant for both (see Table 6.4:11).

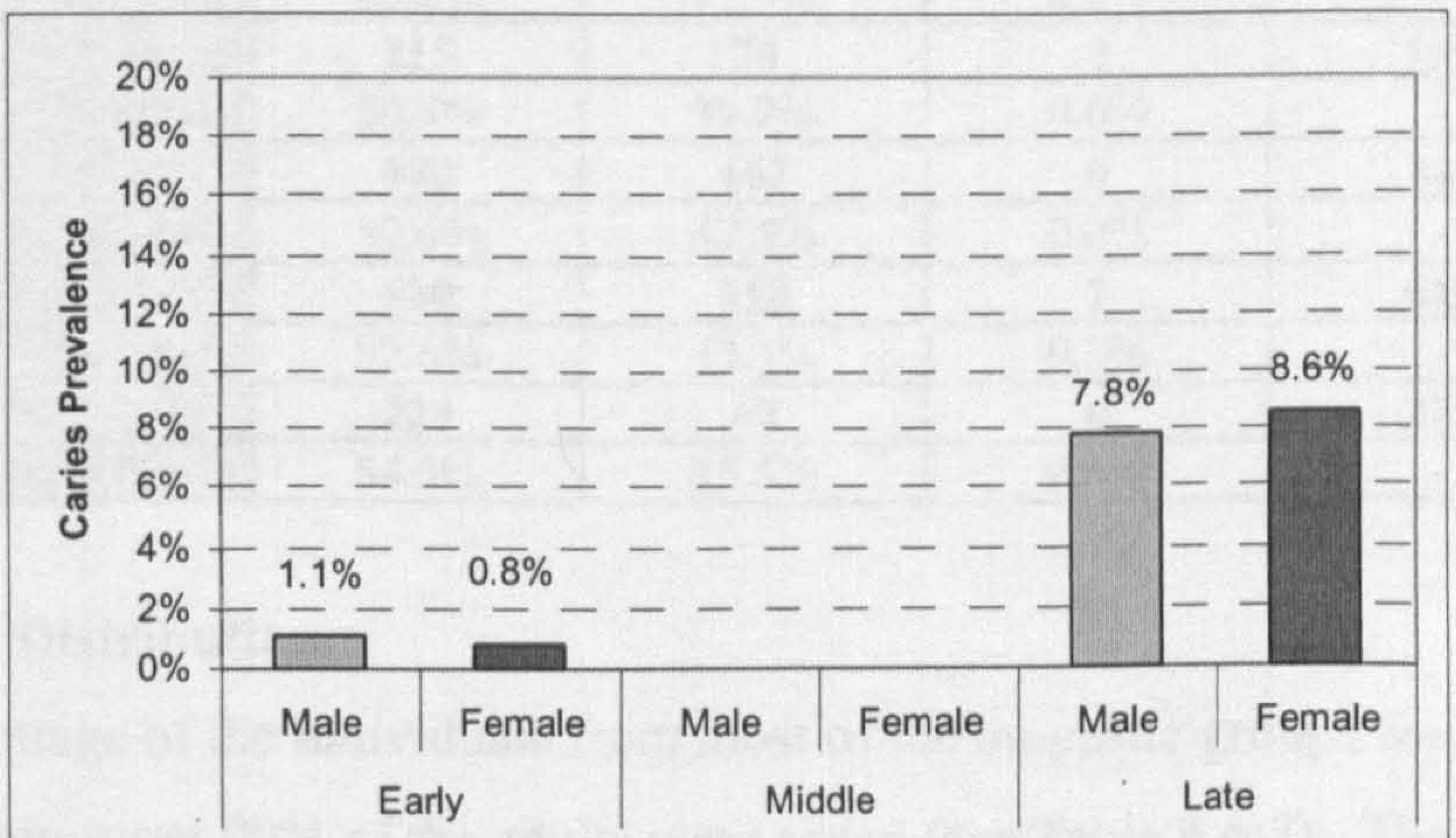


Figure 6.5:8 Caries prevalence in male and female teeth in the monastic sites - Early, Middle and Late Medieval periods.

Table 6.5:19 Comparison of caries prevalence in male and female teeth between pairs of monastic sites – Early and Late Medieval periods: chi-square values and significance level.

Medieval Periods Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Early	Late	21.3674	1	p<0.001	19.8838	1	p<0.001

d.f. = degrees of freedom.

6.6 Late Medieval Sites: Monastic Orders.

6.6.1.1 Proportions of Adults and Subadults.

The four Dominican Friary cemeteries provided the largest sample (642 skeletons), with the smallest sample coming from the one Benedictine cemetery (189). The Augustinian, Dominican and Gilbertine samples all had a large proportion of adults, above 80% (see Table 6.6:1). In contrast the Benedictine and Carmelite samples had an unusually small proportion of adults. Adults made up barely more than half of the Carmelite sample, which had the lowest proportion of adults of all the samples examined in this study. The proportion of adults in the Benedictine sample was similar to that of the Early Medieval monastic sites (compare Table 6.6:1 and Table 6.5:12).

Table 6.6:1 Number of adult, subadult and unaged individuals in the Late Medieval monastic orders.

Monastic Orders		Age: Adult	Subadult	Unaged	Total Skeletons
Augustinian		**216**	**29**	**0**	**245**
	%Total	88.2%	11.8%	0.0%	-
Benedictine		**115**	**74**	**0**	**189**
	%Total	60.8%	39.2%	0.0%	-
Carmelite		**180**	**162**	**0**	**342**
	%Total	52.6%	47.4%	0.0%	-
Dominican		**530**	**110**	**2**	**642**
	%Total	82.6%	17.1%	0.3%	-
Gilbertine		**229**	**42**	**0**	**271**
	%Total	84.5%	15.5%	0.0%	-

6.6.1.2 Sex Distribution.

A high percentage of the individuals from most of the monastic groups were sexed - for three groups, over 90% of the adults were sexed (see Table 6.6:2). The notable exception was the sample from the Carmelite Friaries, where only 65.6% of the adults were sexed. The largest sample of sexed adults (452) came from the four Dominican Friary cemeteries; the smallest samples came from the one Benedictine cemetery (109) and the three Carmelite Friary cemeteries (118).

Most of the monastic orders had significantly more males than females in the sample, with the exception of the Benedictine and Carmelite groups (see Table 6.6:2 and Table 6.6:3). Even though the proportions of males and females in the Benedictine group did not differ significantly from an equal distribution, there was still a higher proportion of males than females. The Carmelite group was somewhat unusual in having precisely 50% of each sex. The Benedictine and Carmelite groups did not differ significantly from each other, but both differed significantly from the other three monastic orders in terms of proportions of males and females (see Table 6.6:4). Although the Augustinian group did not differ significantly from the Dominican and Gilbertine samples, the latter two did differ significantly from each other at the 1% level (Table 6.6:4).

Table 6.6:2 Number and percentage of males, females and unsexed adults in the Late Medieval monastic orders.

Monastic Orders		Sex: Male	Female	Unsexed	Total Sexed Adults	Total Adults
Augustinian		**139**	**58**	**19**	**197**	**216**
	%Total Adults	64.4%	26.9%	8.8%	91.2%	-
	%Sexed Adults	70.6%	29.4%	-	-	-
Benedictine		**61**	**48**	**6**	**109**	**115**
	%Total Adults	53.0%	41.7%	5.2%	94.8%	-
	%Sexed Adults	56.0%	44.0%	-	-	-
Carmelite		**59**	**59**	**62**	**118**	**180**
	%Total Adults	32.8%	32.8%	34.4%	65.6%	-
	%Sexed Adults	50.0%	50.0%	-	-	-
Dominican		**299**	**153**	**78**	**452**	**530**
	%Total Adults	56.4%	28.9%	14.7%	85.3%	-
	%Sexed Adults	66.2%	33.8%	-	-	-
Gilbertine		**173**	**55**	**1**	**228**	**229**
	%Total Adults	75.5%	24.0%	0.4%	99.6%	-
	%Sexed Adults	75.9%	24.1%	-	-	-

Table 6.6:3 Results of chi-square test comparing the proportions of males and females against an expected equal distribution - Late Medieval monastic orders.

Monastic Order		Male	Female	Total	X^2	d.f.	Significant	p
Augustinian	O	139	58	197	33.3046	1	Yes	p<0.001
	E	98.5	98.5					
Benedictine	O	61	48	109	1.5505	1	No	p>0.05
	E	54.5	54.5					
Carmelite	O	59	59	118	0.0000	1	No	p>0.05
	E	59	59					
Dominican	O	299	153	452	47.1593	1	Yes	p<0.001
	E	226	226					
Gilbertine	O	173	55	228	61.0702	1	Yes	p<0.001
	E	114	114					

d.f. = degrees of freedom; **O** = Observed value; **E** = Expected value.

Table 6.6:4 Results of chi-square test comparing the proportions of males and females in pairs of Late Medieval monastic orders.

Monastic Orders Compared		X^2	d.f.	Significant	p
Augustinian	Benedictine	6.6022	1	Yes	p<0.025
Augustinian	Carmelite	13.3594	1	Yes	p<0.001
Augustinian	Dominican	1.2150	1	No	p>0.05
Augustinian	Gilbertine	1.5317	1	No	p>0.05
Benedictine	Carmelite	0.8086	1	No	p>0.05
Benedictine	Dominican	3.9640	1	Yes	p<0.05
Benedictine	Gilbertine	13.7800	1	Yes	p<0.001
Carmelite	Dominican	10.4483	1	Yes	p<0.005
Carmelite	Gilbertine	23.5686	1	Yes	p<0.001
Dominican	Gilbertine	6.7532	1	Yes	p<0.01

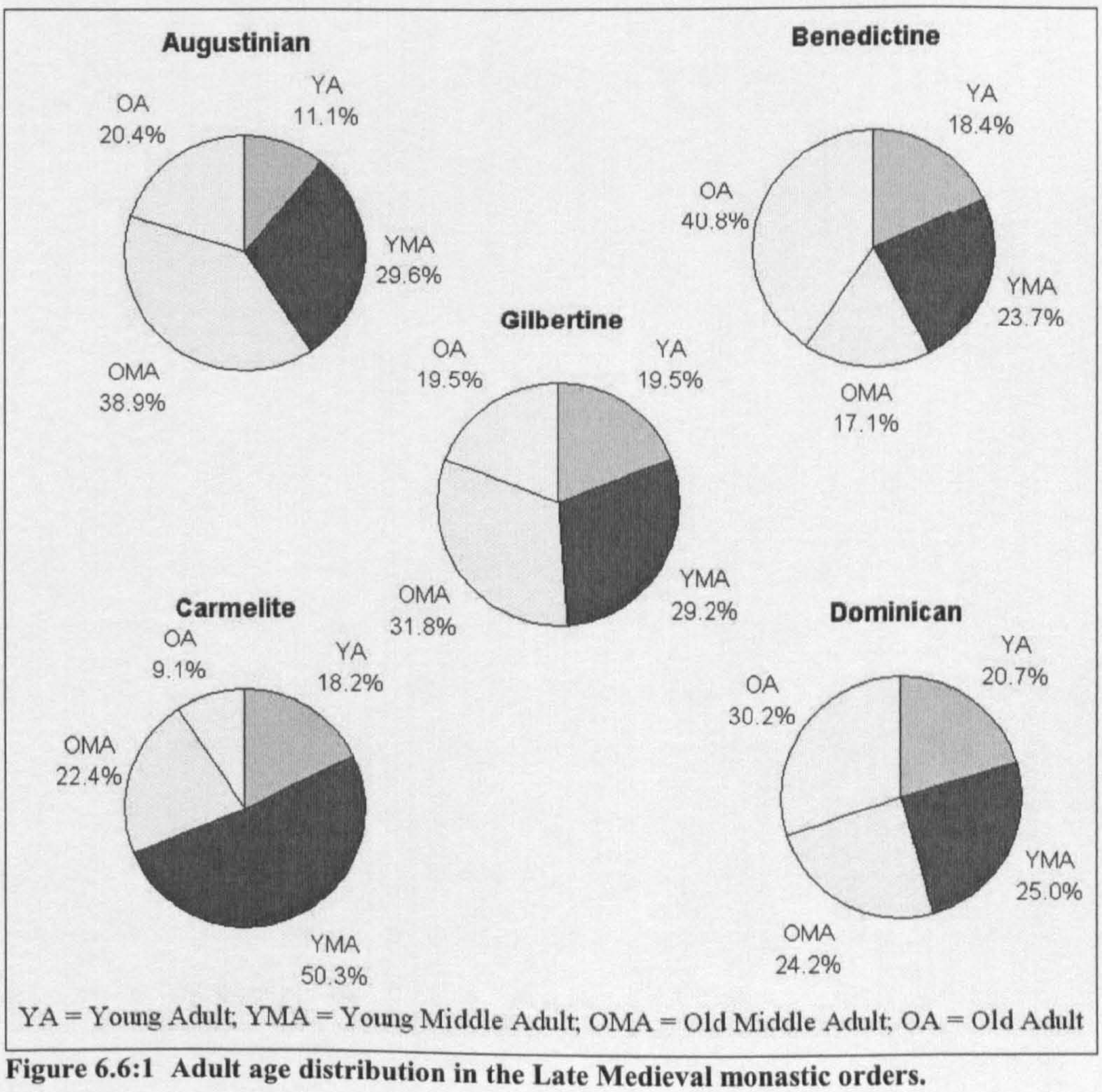
d.f. = degrees of freedom.

6.6.1.3 Age Distribution.

6.6.1.3.1 Adults in General.

The proportion of Aged Adults varied between the different monastic orders (see Table 6.6:5). The Gilbertine sample had the highest proportion of Aged Adults (85.2%), and the Benedictine sample had the lowest (66.1%).

The age distribution of the Carmelite sample was significantly different from all other monastic orders (see Table 6.6:6). Notably, half the adults were placed in the YMA category (50.3%), and, with only 9.1% of the individuals in the OA category, this resulted in the majority of individuals belonging to the two youngest age groups (68.5%). In contrast, at least half of the adults in all other monastic samples were in the oldest two age categories (see Table 6.6:5 and Figure 6.6:1).



YA = Young Adult; YMA = Young Middle Adult; OMA = Old Middle Adult; OA = Old Adult

Figure 6.6:1 Adult age distribution in the Late Medieval monastic orders.

There were no significant differences between the age distributions of the Augustinian, Dominican and Gilbertine samples (see Table 6.6:6). Most of the individuals in the Augustinian sample fell in the middle two age categories (YMA = 29.6% and OMA = 38.9%). The Augustinan sample also had the smallest proportion of individuals in the YA category, at 11.1%, and only 20.4% of the adults were in the OA group. The age distribution in the Gilbertine sample was similar to that in the Augustinian sample, in that most individuals were from the middle two age categories (YMA = 29.2% and OMA = 31.8%), and a similar proportion were in the OA category (19.5%). However, the Gilbertine sample had a larger proportion of individuals in the YA category, at 19.5%. In comparison, the Dominican sample had considerably more individuals in the OA category (30.2%) than both the Augustinian and Gilbertine samples, and a proportion of Young Adults (20.7%) similar to that of the Gilbertine sample, but larger than that of the Augustinian sample (see Table 6.6:5 and Figure 6.6:1).

Table 6.6:5 Number and percentage of adults in each age category in the Late Medieval monastic orders.

Late Medieval Monastic Orders	Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Augustinian	18	48	63	33	162	54	216
	11.1%	29.6%	38.9%	20.4%	75.0%	25.0%	
	66		96				100%
	40.7%		59.3%				
Benedictine	14	18	13	31	76	39	115
	18.4%	23.7%	17.1%	40.8%	66.1%	33.9%	
	32		44				100%
	42.1%		57.9%				
Carmelite	26	72	32	13	143	37	180
	18.2%	50.3%	22.4%	9.1%	79.4%	20.6%	
	98		45				100%
	68.5%		31.5%				
Dominican	76	92	89	111	368	162	530
	20.7%	25.0%	24.2%	30.2%	69.4%	30.6%	
	168		200				100%
	45.7%		54.3%				
Gilbertine	38	57	62	38	195	34	229
	19.5%	29.2%	31.8%	19.5%	85.2%	14.8%	
	95		100				100%
	48.7%		51.3%				
Total	172	287	259	226	944	326	1270
	18.2%	30.4%	27.4%	23.9%	74.3%	25.7%	
	459		485				100%
	48.6%		51.4%				

The Benedictine sample was significantly different from the Augustinian and Gilbertine samples, but not the Dominican sample (see Table 6.6:6). The Benedictine group had the largest proportion of Old Adults of all the monastic orders, at 40.8%, which contributed to it having a high proportion of individuals in the oldest two categories (57.9%). This was second only to the Augustinian sample, where 59.3% of the individuals were in the oldest two age categories. Eighteen percent of the Benedictine individuals were in the YA category, similar to all other monastic groups apart from the Augustinian group.

Table 6.6:6 Results of Kolmogorov-Smirnov tests comparing adult age distributions between Late Medieval monastic orders.

Late Medieval Monastic Orders Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Augustinian / Benedictine	0.2042	Dmax 0.05	0.1891	**Yes**
Augustinian / Carmelite	0.2779	Dmax 0.001	0.2237	**Yes**
Augustinian / Dominican	0.0979	Dmax 0.05	0.1282	No
Augustinian / Gilbertine	0.1093	Dmax 0.05	0.1290	No
Benedictine / Carmelite	0.3170	Dmax 0.001	0.2768	**Yes**
Benedictine / Dominican	0.1063	Dmax 0.05	0.1714	No
Benedictine / Gilbertine	0.2130	Dmax 0.025	0.2001	**Yes**
Carmelite / Dominican	0.2288	Dmax 0.001	0.1922	**Yes**
Carmelite / Gilbertine	0.1981	Dmax 0.005	0.1905	**Yes**
Dominican / Gilbertine	0.2007	Dmax 0.001	0.1542	**Yes**

6.6.1.3.2 Adults: Male and Female Subdivisions.

All cemeteries for the monastic orders provided data on caries prevalence in teeth from males and females, so all are included in this section. The proportion of aged males and females was high (over 80%) for most of the monastic orders (see Table 6.6:7). The only exception was the Benedictine sample, where 77.1% of the females had been aged and 59.0% of the males. In the majority of cases the proportion of aged males and females was higher than that of the adults in general. The two exceptions were the Benedictine males and the Gilbertine females, which both had lower proportions of aged individuals than did the total adults (compare Table 6.6:7 with Table 6.6:5).

In none of the samples for the different monastic orders were the age distributions of males and females significantly different from each other (see Table 6.6:8). In the Augustinian sample the two sexes had very similar age distributions, with most of the individuals in the two older age categories (Male = 60.5%, Female = 56.3%), and both had a similarly low percentage of individuals in the YA group (see Table 6.6:7 and Figure 6.6:2). Again, for the Benedictine sample similar proportions of both sexes were found in the two older age categories (Male = 61.1%, Female = 59.5%), although a higher percentage of males were placed in the OA category (50.0%) compared to the females (35.1%). There was also a higher proportion of males in the YA group (22.2%) than females (10.8%).

Table 6.6:7 Number and percentage of males and females in the Late Medieval monastic orders.

Late Medieval Monastic Orders		Aged Adults (% Total Aged): Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Augustinian	Male	12	33	46	23	114	25	139
		10.5%	28.9%	40.4%	20.2%	82.0%	18.0%	
		45		69				100%
		39.5%		60.5%				
	Female	6	15	17	10	48	10	58
		12.5%	31.3%	35.4%	20.8%	82.8%	17.2%	
		21		27				100%
		43.8%		56.3%				
Benedictine	Male	8	6	4	18	36	25	61
		22.2%	16.7%	11.1%	50.0%	59.0%	41.0%	
		14		22				100%
		38.9%		61.1%				
	Female	4	11	9	13	37	11	48
		10.8%	29.7%	24.3%	35.1%	77.1%	22.9%	
		15		22				100%
		40.5%		59.5%				
Carmelite	Male	6	25	17	6	54	5	59
		11.1%	46.3%	31.5%	11.1%	91.5%	8.5%	
		31		23				100%
		57.4%		42.6%				
	Female	10	32	9	2	53	6	59
		18.9%	60.4%	17.0%	3.8%	89.8%	10.2%	
		42		11				100%
		79.2%		20.8%				
Dominican	Male	29	44	49	56	178	28	206
		16.3%	24.7%	27.5%	31.5%	86.4%	13.6%	❶
		73		105				100%
		41.0%		59.0%				
	Female	11	21	18	37	87	14	101
		12.6%	24.1%	20.7%	42.5%	86.1%	13.9%	❷
		32		55				100%
		36.8%		63.2%				
Gilbertine	Male	31	43	46	30	150	23	173
		20.7%	28.7%	30.7%	20.0%	86.7%	13.3%	
		74		76				100%
		49.3%		50.7%				
	Female	7	14	16	8	45	10	55
		15.6%	31.1%	35.6%	17.8%	81.8%	18.2%	
		21		24				100%
		46.7%		53.3%				
Totals	Male	86	151	162	133	532	106	638
		16.2%	28.4%	30.5%	25.0%	83.4%	16.6%	❶
		237		295				100%
		44.5%		55.5%				
	Female	38	93	69	70	270	51	321
		14.1%	34.4%	25.6%	25.9%	84.1%	15.9%	❷
		131		139				100%
		48.5%		51.5%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and ❷ 52 females from Blackfriars, Carlisle as details of age distribution were not provided.

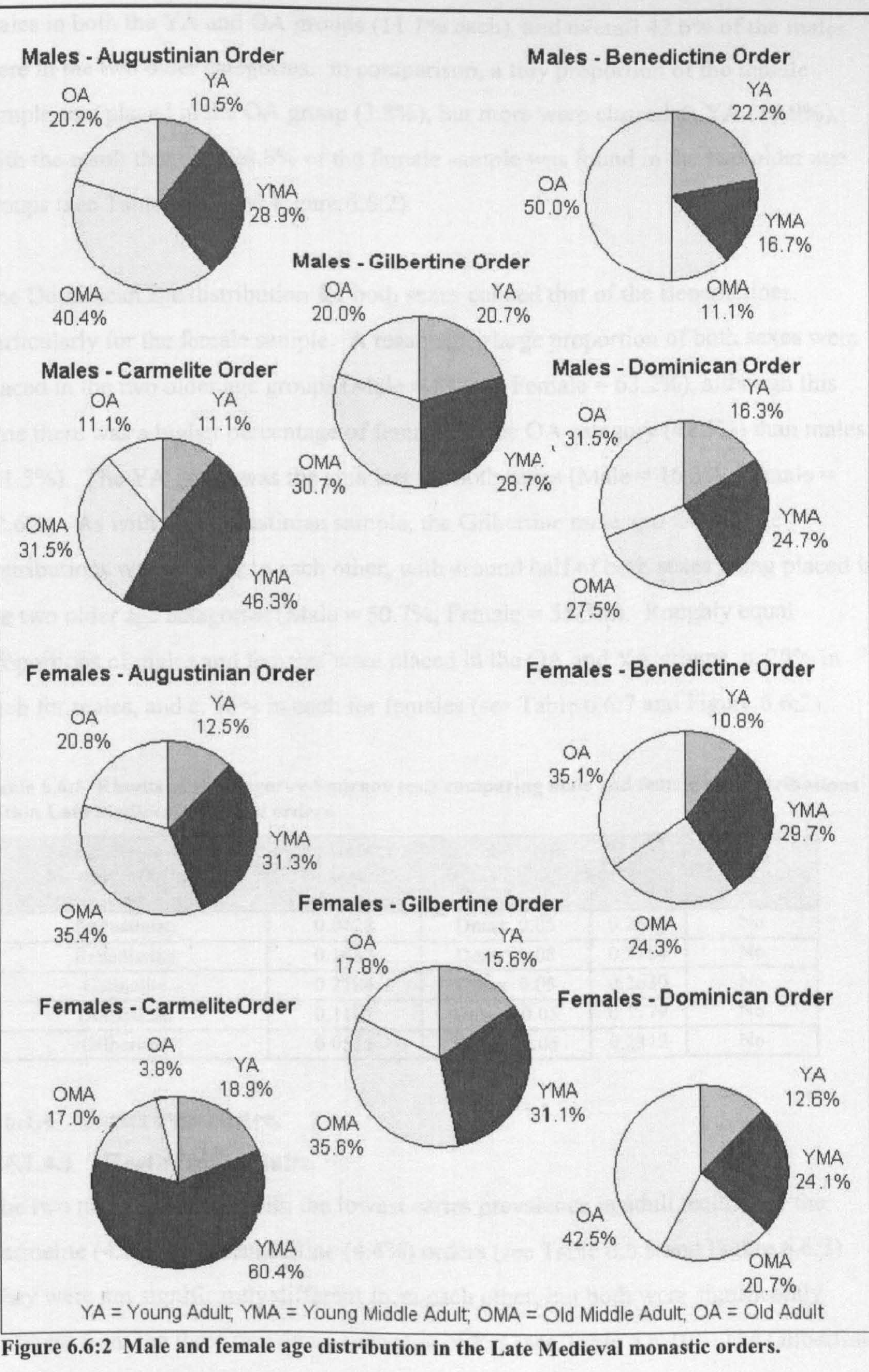


Figure 6.6:2 Male and female age distribution in the Late Medieval monastic orders.

In the Carmelite sample the majority of individuals of both sexes had been placed in the YMA category (Male = 46.3%, Female = 60.4%). There were small proportions of males in both the YA and OA groups (11.1% each), and overall 42.6% of the males were in the two older categories. In comparison, a tiny proportion of the female sample was placed in the OA group (3.8%), but more were classed as YA (18.9%), with the result that only 20.8% of the female sample was found in the two older age groups (see Table 6.6:7 and Figure 6.6:2).

The Dominican age distribution for both sexes echoed that of the Benedictines, particularly for the female sample. A reasonably large proportion of both sexes were placed in the two older age groups (Male = 59.0%, Female = 63.2%), although this time there was a higher percentage of females in the OA category (42.5%) than males (31.5%). The YA group was the smallest for both sexes (Male = 16.3%, Female = 12.6%). As with the Augustinian sample, the Gilbertine male and female age distributions were similar to each other, with around half of both sexes being placed in the two older age categories (Male = 50.7%, Female = 55.3%). Roughly equal proportions of males and females were placed in the OA and YA groups, c. 20% in each for males, and c. 16% in each for females (see Table 6.6:7 and Figure 6.6:2).

Table 6.6:8 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within Late Medieval monastic orders.

Late Medieval Monastic Orders Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Augustinian	0.0428	Dmax 0.05	0.2340	No
Benedictine	0.1487	Dmax 0.05	0.3184	No
Carmelite	0.2184	Dmax 0.05	0.2630	No
Dominican	0.1107	Dmax 0.05	0.1779	No
Gilbertine	0.0511	Dmax 0.05	0.2312	No

6.6.1.4 Caries Prevalence.

6.6.1.4.1 Teeth from Adults.

The two monastic orders with the lowest caries prevalence in adult teeth were the Carmelite (4.1%) and Benedictine (4.4%) orders (see Table 6.6:9 and Figure 6.6:3). They were not significantly different from each other, but both were significantly different from the three remaining monastic orders (see Table 6.6:10). The Gilbertine sample had the largest caries prevalence (12.1%), which was significantly different from all other monastic samples (see Table 6.6:10). The Augustinian and Dominican groups, with caries prevalence rates of 7.3% and 8.1% respectively, were not significantly different from each other, but were significantly different from the

Benedictine, Carmelite and Gilbertine samples (see Table 6.6:10).

Table 6.6:9 Caries prevalence in Late Medieval monastic orders.

Monastic Orders	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Augustinian	214	2,945	7.3%	170	2,159	7.9%	44	786	5.6%
Benedictine	42	957	4.4%	9	400	2.3%	30	524	5.7%
Carmelite	99	2,409	4.1%	28	989	2.8%	49	912	5.4%
Dominican	457	5,623	8.1%	275	3,594	7.7%	173	1,793	9.6%
Gilbertine	356	2,945	12.1%	247	2,263	10.9%	109	682	16.0%

C = With Caries; P = Number of teeth present.
See **Appendix 13** for source data for each category.

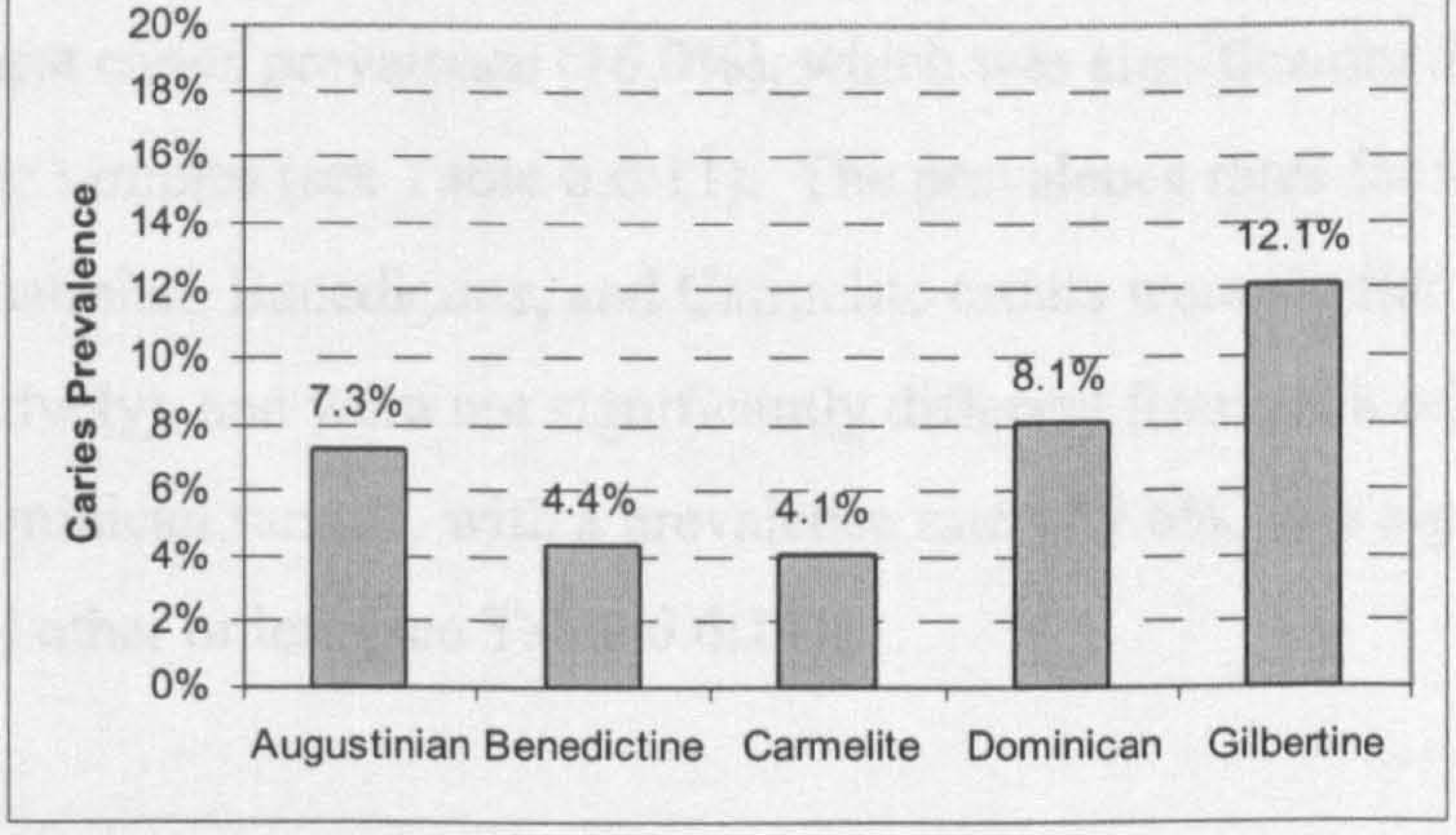


Figure 6.6:3 Caries prevalence in adult teeth in the Late Medieval monastic orders.

Table 6.6:10 Results of chi-square test comparing caries prevalence (adult teeth) in pairs of Late Medieval monastic orders.

Monastic Orders Compared		X^2	d.f.	Significant	p
Augustinian	Benedictine	9.7580	1	**Yes**	p<0.005
Augustinian	Carmelite	23.9927	1	**Yes**	p<0.001
Augustinian	Dominican	1.9840	1	No	p>0.05
Augustinian	Gilbertine	39.1657	1	**Yes**	p<0.001
Benedictine	Carmelite	0.1330	1	No	p>0.05
Benedictine	Dominican	16.3100	1	**Yes**	p<0.001
Benedictine	Gilbertine	46.7488	1	**Yes**	p<0.001
Carmelite	Dominican	42.2522	1	**Yes**	p<0.001
Carmelite	Gilbertine	108.479	1	**Yes**	p<0.001
Dominican	Gilbertine	35.3069	1	**Yes**	p<0.001

d.f. = degrees of freedom.

6.6.1.4.2 Teeth from Adult Male and Female Subdivisions.

The results for the male and female teeth are displayed in Table 6.6:9 and Figure 6.6:4.

The pattern of caries prevalence observed for the adult teeth holds true for the teeth from males: the two groups with the lowest caries prevalence rates were the Benedictine (2.3%) and Carmelite (2.8%) samples (not significantly different from each other but both significantly different from all other orders, see Table 6.6:11), the highest prevalence rate was in the Gilbertine sample (10.9%; significantly different from all other orders, see Table 6.6:11), and the Augustinian and Dominican samples had similar prevalence rates (7.9% and 7.7% respectively) that lay between the two extremes. These latter two were not significantly different from each other, but were both significantly different from the remaining monastic orders (see Table 6.6:11).

The pattern for the female teeth was different in some respects. The Gilbertine sample still had the highest caries prevalence (16.0%), which was significantly different from all other monastic samples (see Table 6.6:11). The prevalence rates for the female teeth in the Augustinian, Benedictine, and Carmelite orders were similar (5.6%, 5.7% and 5.4% respectively), and were not significantly different from each other (see Table 6.6:11). The Dominican sample, with a prevalence rate of 9.6%, was significantly different from all other orders (see Table 6.6:11).

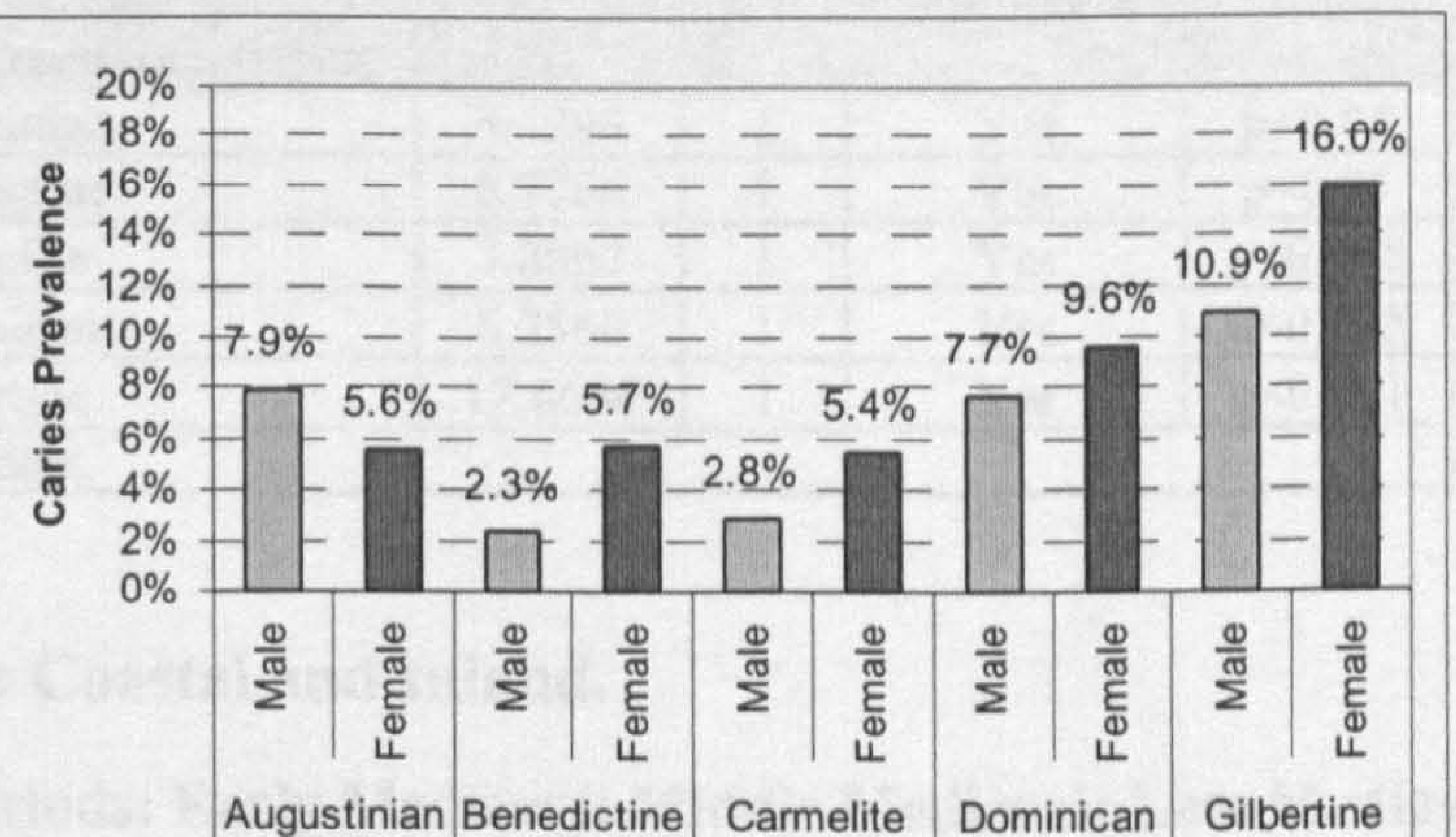


Figure 6.6:4 Caries prevalence in male and female teeth in the Late Medieval monastic orders.

Table 6.6:11 Comparison of caries prevalence in male and female teeth between pairs of Late Medieval monastic orders: chi-square values and significance level.

Monastic Orders Compared		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Augustinian	Benedictine	16.4076	1	p<0.001	0.0095	1	p>0.05
Augustinian	Carmelite	29.2653	1	p<0.001	0.0413	1	p>0.05
Augustinian	Dominican	0.0935	1	p>0.05	11.6351	1	p<0.001
Augustinian	Gilbertine	11.9601	1	p<0.001	42.1776	1	p<0.001
Benedictine	Carmelite	0.3710	1	p>0.05	0.0795	1	p>0.05
Benedictine	Dominican	15.9003	1	p<0.001	7.8086	1	p<0.01
Benedictine	Gilbertine	29.3703	1	p<0.001	30.5733	1	p<0.001
Carmelite	Dominican	29.1892	1	p<0.001	14.6708	1	p<0.001
Carmelite	Gilbertine	58.0934	1	p<0.001	49.1874	1	p<0.001
Dominican	Gilbertine	18.2132	1	p<0.001	19.6326	1	p<0.001

d.f. = degrees of freedom.

The difference between the caries prevalence rate in male and female teeth was significant for all five monastic orders (see Table 6.6:12). It was only in the Augustinian sample where male teeth had a higher prevalence rate than female teeth. In the remaining four orders caries prevalence in female teeth was higher than that in male teeth. The largest difference was seen in the Gilbertine sample, where caries was found in 16.0% of the female teeth compared to 10.9% of the male teeth.

Table 6.6:12 Results of chi-square test comparing caries prevalence between male and female teeth within each Late Medieval monastic order.

Monastic Orders Male and Female teeth compared	X^2	d.f.	Significant	p
Augustinian	4.4299	1	Yes	p<0.05
Benedictine	6.7766	1	Yes	p<0.01
Carmelite	7.8867	1	Yes	p<0.005
Dominican	6.2566	1	Yes	p<0.025
Gilbertine	12.6646	1	Yes	p<0.001

d.f. = degrees of freedom.

6.7 Location: Coastal and Inland.

6.7.1 Main Periods: Early Medieval; Middle Medieval; Late Medieval.

6.7.1.1 Proportions of Adults and Subadults.

The largest number of skeletons was found in the Late Medieval coastal sample (3413 when the 146 skeletons from Ensay are included). The Late Medieval sample also had the largest inland sample (1997; see Table 6.7:1). The number of skeletons in all groups was over a thousand, with the notable exception of the Middle Medieval coastal sample, which consisted of the 95 individuals from School Street, Ipswich.

Table 6.7:1 Number of adult, subadult and unaged individuals in coastal and inland sites - Early, Middle and Late Medieval periods.

Medieval Period Coastal / Inland			Age			
			Adult	Subadult	Unaged	Total Skeletons
Early	Coastal		764	290	21	1056
		%Total	72.3%	27.5%	2.0%	-
	Inland		975	455	9	1439
		%Total	67.8%	31.6%	0.6%	-
Middle	Coastal		79	16	0	95
		%Total	83.2%	16.8%	0.0%	-
	Inland		877	483	2	1362
		%Total	64.4%	35.5%	0.1%	-
Late	Coastal		2320	943	4	3267 ❶
		%Total	71.0%	28.9%	0.1%	-
	Inland		1512	484	1	1997
		%Total	75.7%	24.2%	0.1%	-

These data exclude - ❶ 146 skeletons from the Isle of Ensay data-set, as there were no data for numbers of adults and subadults.

Although the Early Medieval coastal sites had a smaller number of individuals than the inland sites, a larger proportion of them were adults: 72.3% compared to 67.8% (see Table 6.7:1). The coastal sites also had a larger proportion of unaged individuals (2.0%). The Middle Medieval sites provided far more individuals for the inland sample compared to the coastal sample. A high percentage of the individuals in the coastal sample were adults (83.2%), but the inland sample had a lower proportion (64.4%). For the Late Medieval period, the coastal sample was larger than the inland sample. A smaller proportion of the individuals from the coastal sample were adults (71.0%) compared to the inland sample (75.7%; see Table 6.7:1).

6.7.1.2 Sex Distribution.

This section only discusses those data-sets that provided data on caries prevalence in males and females, but again the Late Medieval coastal site had the most skeletons (1227), and the sample with the least skeletons was the Middle Medieval coastal site (79). All other groups had a sample size of over 500 individuals (see Table 6.7:2).

Table 6.7:2 Number and percentage of males, females and unsexed adults in coastal and inland sites - Early, Middle and Late Medieval periods.

Medieval Period Coastal / Inland			Sex				
			Male	**Female**	**Unsexed**	**Total Sexed Adults**	**Total Adults**
Early	**Coastal**		**237**	**231**	**100**	**468**	**568**
		%Total Adults	41.7%	40.7%	17.6%	82.4%	-
		%Sexed Adults	50.6%	49.4%	-	-	-
	Inland		**372**	**373**	**141**	**745**	**886**
		%Total Adults	42.0%	42.1%	15.9%	84.1%	-
		%Sexed Adults	49.9%	50.1%	-	-	-
Middle	**Coastal**		**35**	**28**	**16**	**63**	**79**
		%Total Adults	44.3%	35.4%	20.3%	79.7%	-
		%Sexed Adults	55.6%	44.4%	-	-	-
	Inland		**273**	**222**	**25**	**495**	**520**
		%Total Adults	52.5%	42.7%	4.8%	95.2%	-
		%Sexed Adults	55.2%	44.8%	-	-	-
Late	**Coastal**		**695**	**364**	**168**	**1059**	**1227**
		%Total Adults	56.6%	29.7%	13.7%	86.3%	-
		%Sexed Adults	65.6%	34.4%			
	Inland		**367**	**226**	**55**	**593**	**648**
		%Total Adults	56.6%	34.9%	8.5%	91.5%	-
		%Sexed Adults	61.9%	38.1%	-	-	-

A similar proportion of adults had been sexed in both the inland and coastal Early Medieval sites (84.1% and 82.4% respectively), and the proportion of individuals in the different sex categories was also similar between each group (see Table 6.7:2). Neither sample was significantly different from the expected equal distribution of males and females (coastal sample: $X^2 = 0.0769$, $p>0.05$, d.f. = 1; inland sample: $X^2 = 0.0013$, $p>0.05$, d.f. = 1), nor were they significantly different from each other ($X^2 = 0.0577$, $p>0.05$, d.f. = 1).

In the Middle Medieval period the coastal sample, based on only one site, was considerably smaller than the inland sample, drawn from five sites. A larger proportion of the adults in the coastal sample were unsexed (20.3%) compared to the inland sample (4.8%; see Table 6.7:2). Although the proportion of males and females in both samples was similar, and did not differ significantly from each other ($X^2 = 0.0037$, $p>0.05$, d.f. = 1), the proportions in the coastal sample did not differ significantly from an even distribution ($X^2 = 0.7778$, $p>0.05$, d.f. = 1) whereas the inland sample did ($X^2 = 5.2545$, $p<0.025$, d.f. = 1).

The Late Medieval coastal sample was almost double the size of the inland sample, but a higher proportion of the adults from the inland sample could be sexed (91.5%

compared to 86.3%; see Table 6.7:2). The samples were not significantly different from each other in terms of the proportions of males and females ($X^2 = 2.3150$, $p>0.05$, d.f. = 1), and both were significantly different from the expected even distribution of the sexes (coastal: $X^2 = 103.457$, $p<0.001$, d.f. = 1; inland: $X^2 = 33.5261$, $p<0.001$, d.f. = 1).

6.7.1.3 Age Distribution.

6.7.1.3.1 Adults in General.

The proportion of Aged Adults in the coastal and inland Early Medieval samples was almost identical (73.8% and 73.9% respectively; see Table 6.7:3). However, the distribution of adults between the age categories in the two samples was significantly different (see Table 6.7:4). The majority of the adults in the inland sample were in the two youngest age categories (58.5%). In contrast, for the coastal sample the two age categories with the most individuals were the OA (28.9%) and OMA (25.7%), so 54.6% of the adults were in the two older categories combined (see Table 6.7:3 and Figure 6.7:1).

For the Middle Medieval period far more of the inland sample could be assigned to an age category (79.9%) than could the coastal sample (65.8%; see Table 6.7:3). In both coastal and inland samples the majority of individuals were in the two youngest age categories rather than the two oldest. The inland sample had a larger proportion of individuals in the YA category (27.5%) and smaller proportion in the OA category (15.1%) than did the coastal sample (YA = 23.1% and OA = 23.1%; see Table 6.7:3 and Figure 6.7:1). Despite this, there was no significant difference between the two samples (see Table 6.7:4).

The proportion of Aged Adults in the coastal and inland Late Medieval samples was similar, at 74.8% and 71.5% respectively (see Table 6.7:3). Most individuals were found in the middle two age categories, with the age group with the smallest proportion of individuals being the YA category (see Table 6.7:3 and Figure 6.7:1). As for the Middle Medieval period, there was no significant difference between each sample with regard to age distribution (see Table 6.7:4).

Table 6.7:3 Number and percentage of adults in different age categories in coastal and inland sites - Early, Middle and Late Medieval periods.

Medieval Period Coastal / Inland		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Early	Coastal	125	131	145	163	564	200	764
		22.2%	23.2%	25.7%	28.9%	73.8%	26.2%	
		256		308				100%
		45.4%		54.6%				
	Inland	204	218	145	154	721	254	975
		28.3%	30.2%	20.1%	21.4%	73.9%	26.1%	
		422		299				100%
		58.5%		41.5%				
Middle	Coastal	12	16	12	12	52	27	79
		23.1%	30.8%	23.1%	23.1%	65.8%	34.2%	
		28		24				100%
		53.8%		46.2%				
	Inland	131	134	139	72	476	120	596
		27.5%	28.2%	29.2%	15.1%	79.9%	20.1%	❶
		265		211				100%
		55.7%		44.3%				
Late	Coastal	294	567	503	359	1723	581	2304
		17.1%	32.9%	29.2%	20.8%	74.8%	25.2%	❷
		861		862				100%
		50.0%		50.0%				
	Inland	207	319	297	258	1081	431	1512
		19.1%	29.5%	27.5%	23.9%	71.5%	28.5%	
		526		555				100%
		48.7%		51.3%				
Totals	Coastal	431	714	660	534	2339	808	3147
		18.4%	30.5%	28.2%	22.8%	74.3%	25.7%	❷
		1145		1194				100%
		49.0%		51.0%				
	Inland	542	671	581	484	2278	805	3083
		23.8%	29.5%	25.5%	21.2%	73.9%	26.1%	❶
		1213		1065				100%
		53.2%		46.8%				

These data exclude - ❶ 202 adults from Trowbridge, as they are only placed in two broad categories, and ❷ 78 adults from Whithorn B and 84 of the 146 skeletons from the Isle of Ensay, for which there were no data on age.

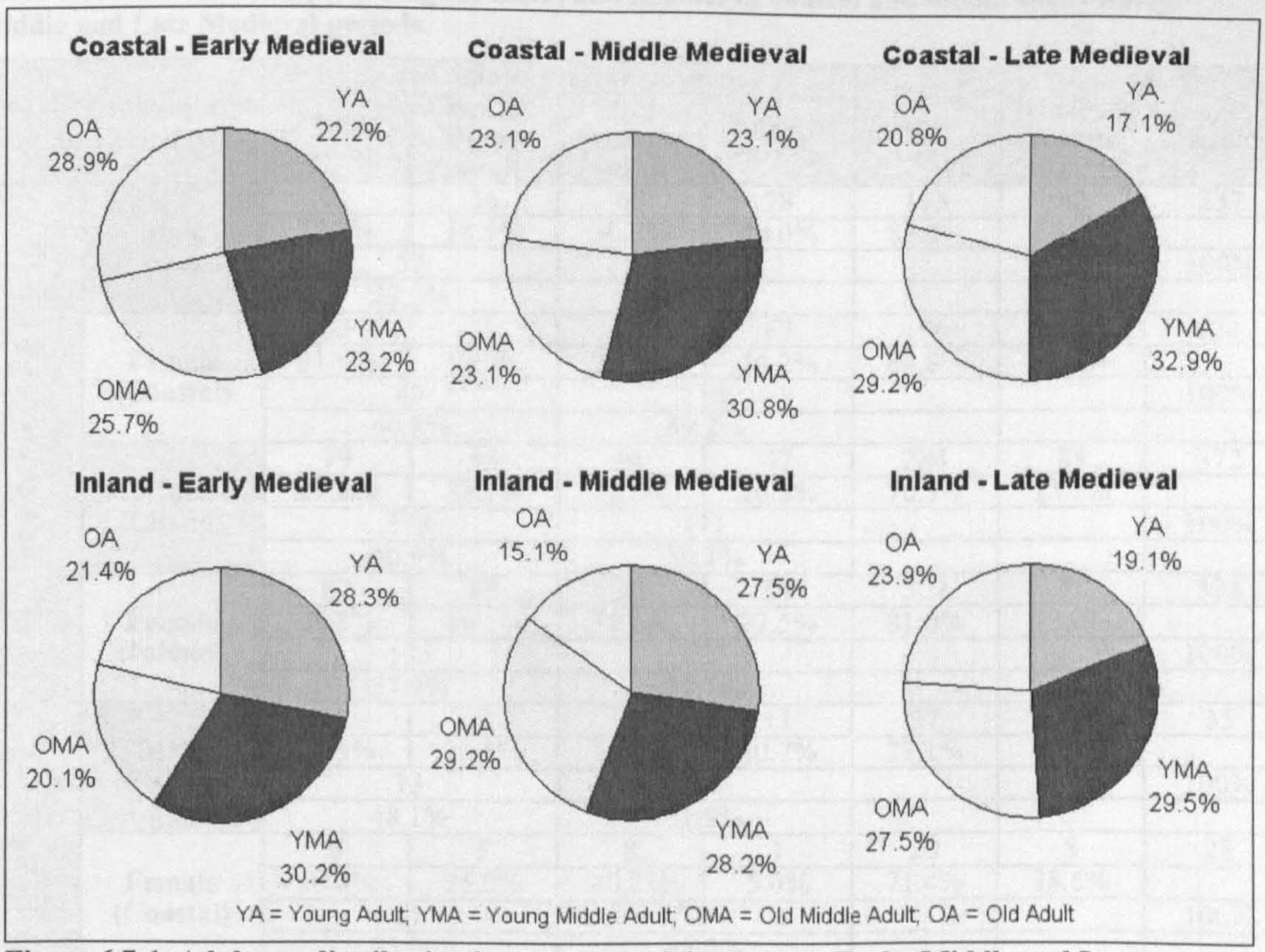


Figure 6.7:1 Adult age distribution in coastal and inland sites - Early, Middle and Late Medieval periods.

Table 6.7:4 Results of Kolmogorov-Smirnov tests comparing adult age distributions between coastal and inland sites - Early, Middle and Late Medieval periods.

Coastal / Inland Sites Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early Medieval	0.1314	Dmax 0.001	0.1096	**Yes**
Middle Medieval	0.0795	Dmax 0.05	0.1986	No
Late Medieval	0.0303	Dmax 0.05	0.0528	No

6.7.1.3.2 Adults: Male and Female Subdivisions.

In all the coastal and inland samples from the Early Medieval, Middle Medieval and Late Medieval periods the proportion of Aged Adults of both sexes was higher than the proportion of Aged Adults in general (compare Table 6.7:5 with Table 6.7:3).

Table 6.7:5 Number and percentage of males and females in coastal and inland sites - Early, Middle and Late Medieval periods.

Coastal / Inland sites by period		Aged Adults (% Total Aged): Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Early Medieval	Male (Coastal)	21	36	60	78	195	42	237
		10.8%	18.5%	30.8%	40.0%	82.3%	17.7%	
		57		138				100%
		29.2%		70.8%				
	Female (Coastal)	43	37	49	67	196	35	231
		21.9%	18.9%	25.0%	34.2%	84.8%	15.2%	
		80		116				100%
		40.8%		59.2%				
	Male (Inland)	79	94	64	47	284	88	372
		27.8%	33.1%	22.5%	16.5%	76.3%	23.7%	
		173		111				100%
		60.9%		39.1%				
	Female (Inland)	87	88	59	68	302	71	373
		28.8%	29.1%	19.5%	22.5%	81.0%	19.0%	
		175		127				100%
		57.9%		42.1%				
Middle Medieval	Male (Coastal)	5	8	3	11	27	8	35
		18.5%	29.6%	11.1%	40.7%	77.1%	22.9%	
		13		14				100%
		48.1%		51.9%				
	Female (Coastal)	6	5	8	1	20	8	28
		30.0%	25.0%	40.0%	5.0%	71.4%	28.6%	
		11		9				100%
		55.0%		45.0%				
	Male (Inland)	61	61	73	36	231	42	273
		26.4%	26.4%	31.6%	15.6%	84.6%	15.4%	
		122		109				100%
		52.8%		47.2%				
	Female (Inland)	56	54	48	22	180	42	222
		31.1%	30.0%	26.7%	12.2%	81.1%	18.9%	
		110		70				100%
		61.1%		38.9%				
Late Medieval	Male (Coastal)	91	118	140	156	505	97	602
		18.0%	23.4%	27.7%	30.9%	83.9%	16.1%	❶
		209		296				100%
		41.4%		58.6%				
	Female (Coastal)	48	85	61	76	270	42	312
		17.8%	31.5%	22.6%	28.1%	86.5%	13.5%	❷
		133		137				100%
		49.3%		50.7%				
	Male (Inland)	76	93	84	70	323	44	367
		23.5%	28.8%	26.0%	21.7%	88.0%	12.0%	
		169		154				100%
		52.3%		47.7%				
	Female (Inland)	31	56	50	60	197	29	226
		15.7%	28.4%	25.4%	30.5%	87.2%	12.8%	
		87		110				100%
		44.2%		55.8%				

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Table 6.7:5 (Continued).

Coastal / Inland sites by period		Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
		Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Totals	Male (Coastal)	117	162	203	245	727	147	874
		16.1%	22.3%	27.9%	33.7%	83.2%	16.8%	❶
		279		448				100%
		38.4%		61.6%				
	Female (Coastal)	97	127	118	144	486	85	571
		20.0%	26.1%	24.3%	29.6%	85.1%	14.9%	❷
		46.1%		53.9%				
	Male (Inland)	216	248	221	153	838	174	1012
		25.8%	29.6%	26.4%	18.3%	82.8%	17.2%	
		464		374				100%
		55.4%		44.6%				
	Female (Inland)	174	198	157	150	679	142	821
		25.6%	29.2%	23.1%	22.1%	82.7%	17.3%	
		372		307				100%
		54.8%		45.2%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and ❷ 52 females from Blackfriars, Carlisle, as details of age distribution were not provided.

In the Early Medieval coastal sample there was a high proportion of both males and females in the two older age groups (Male = 70.8%, Female = 59.2%), and in the OA category in particular (Male = 40.0%, Female = 34.2%). A higher percentage of females (21.9%) than males (10.8%) was placed in the YA group (see Table 6.7:5 and Figure 6.7:2). Again, the age distribution for males and females from the inland sites was similar to each other, with 27.8% of males and 28.8% of females in the YA category, although proportionally slightly more females than males were placed in the OA category. For neither coastal nor inland samples were the age distributions between the two sexes found to be significantly different (Table 6.7:6). Both the coastal male and female age distributions were significantly different from the inland male and female age distributions (see Table 6.7:6). Of the coastal males 70.8% were placed in the two older age groups, with 40.0% in the OA category. The opposite trend was seen in the inland sites, with 60.9% of the males in the younger two age groups, and only 16.5% in the OA category. A similar trend was observed in the females, although the differences were not as extreme.

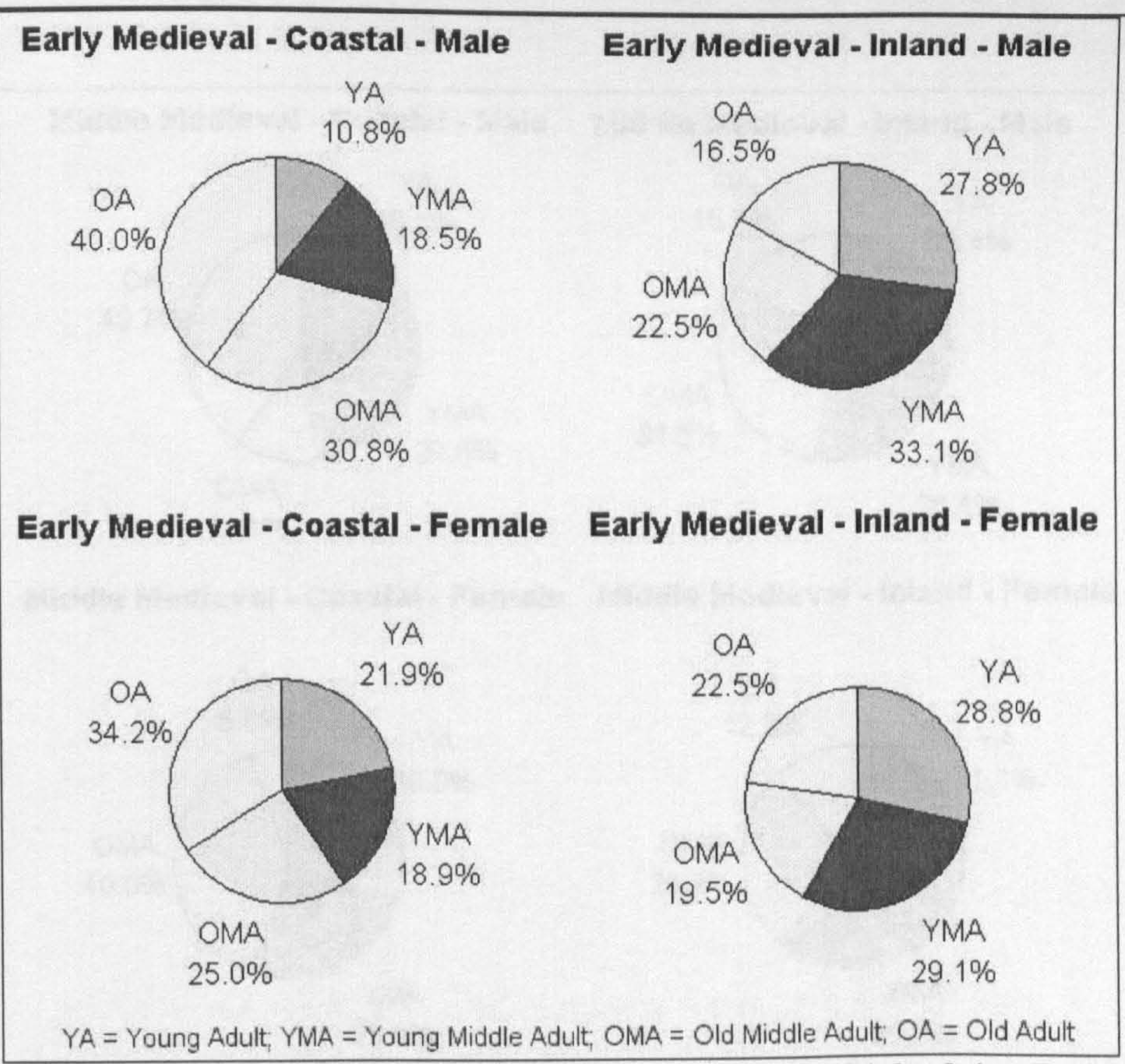

Figure 6.7:2 Male and female age distributions in coastal and inland sites Early Medieval period.

The Middle Medieval coastal sample had a slightly higher proportion of males (51.9%) than females (45.0%) in the two older age groups, but whereas the males were mainly in the OA group (40.7%), the females were mainly in the OMA group (40.0%), with only 5.0% in the OA group (see Table 6.7:5 and Figure 6.7:3). There was also a higher proportion of females (30.0%) in the YA category compared to males (18.5%). The inland sample also had a higher percentage of males (47.2%) than females (38.9%) in the two older categories, but unlike the coastal sample the distribution within these categories was similar for both sexes. Again, a higher proportion of females were found in the YA group (31.1%) compared to 26.4% of the males (see Table 6.7:5 and Figure 6.7:3). These differences were not found to be significant for either the coastal or inland samples (see Table 6.7:6). Neither were there significant differences between inland and coastal samples regarding the age distributions of both sexes (see Table 6.7:7). The main differences existed in the older age categories, where the coastal males had a particularly large proportion of individuals in the OA group compared to the inland males.

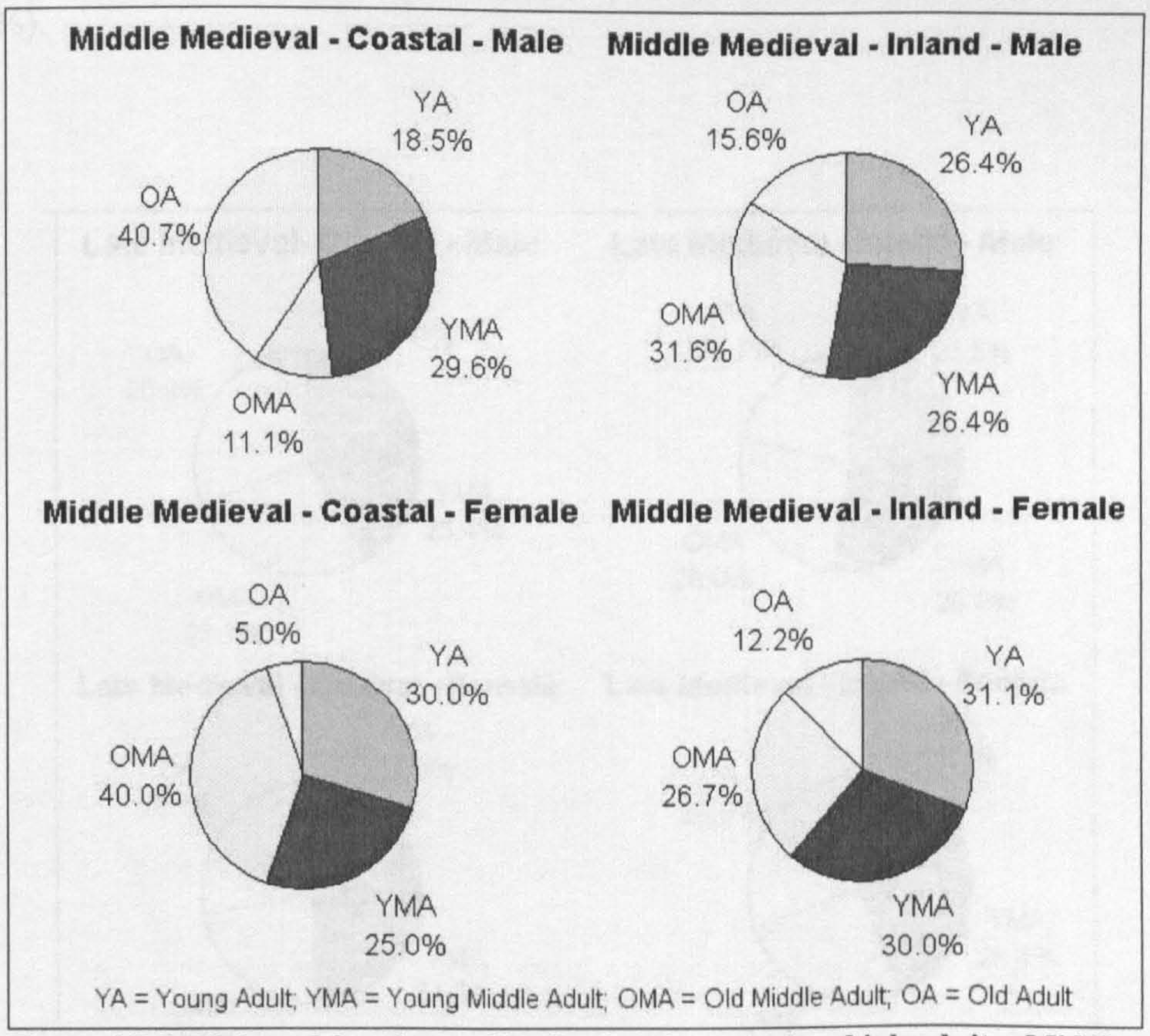

Figure 6.7:3 Male and female age distributions in coastal and inland sites Middle Medieval period.

As for the previous two periods, the Late Medieval sample had a higher proportion of males than females in the two older categories in the coastal sample (see Table 6.7:5 and Figure 6.7:4). Both sexes had a similar proportion in the OA (Male = 30.9%, Female = 28.1%) and YA (Male = 18.0%, Female = 17.8%) age groups. In contrast to the coastal sample the inland sites had a higher proportion of females in the two older age groups (55.8%) than males (47.7%), and there were proportionally more females in the OA category (30.5%) than males (21.7%). A higher percentage of males (23.5%) were found in the YA group compared to females (15.7%). There were no significant differences between the age distributions for both sexes in either the coastal or inland sample (see Table 6.7:6). The age distribution of the coastal females was not significantly different from the inland females, but the age distribution of the coastal males was significantly different from that of the inland males (see Table 6.7:7). There were proportionally more males in the older age categories (58.6%), especially the OA group (30.9%), in the coastal sample than in the inland sample

(47.7% and 21.7% respectively), and fewer in the YA group (coastal = 18.0%, inland = 23.5%).

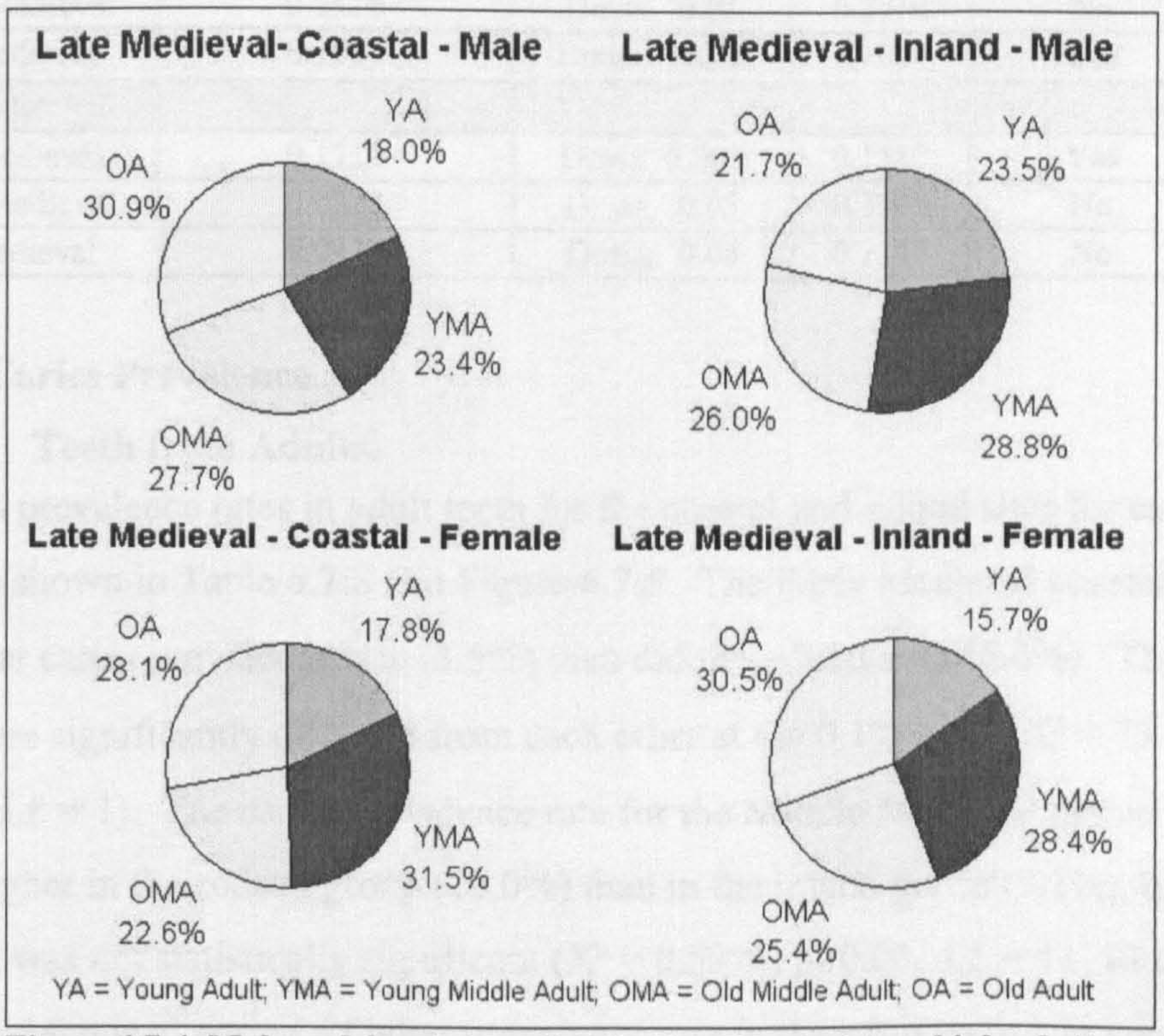

Figure 6.7:4 Male and female age distributions in coastal and inland sites Late Medieval period.

Table 6.7:6 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within coastal and inland sites - Early, Middle and Late Medieval periods.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Early Medieval - Coastal	0.1159	Dmax 0.05	0.1376	No
Early Medieval - Inland	0.0597	Dmax 0.05	0.1124	No
Middle Medieval - Coastal	0.3574	Dmax 0.05	0.4012	No
Middle Medieval - Inland	0.0830	Dmax 0.05	0.1352	No
Late Medieval - Coastal	0.0787	Dmax 0.05	0.1025	No
Late Medieval - Inland	0.0832	Dmax 0.05	0.115	No

Table 6.7:7 Results of Kolmogorov-Smirnov tests comparing male age distributions, and female age distributions, between coastal and inland sites - Early, Middle and Late Medieval periods.

Coastal / Inland Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Males:				
Early Medieval	0.3168	Dmax 0.001	0.1814	**Yes**
Middle Medieval	0.2516	Dmax 0.05	0.2766	No
Late Medieval	0.1094	Dmax 0.025	0.1054	**Yes**
Females:				
Early Medieval	0.1713	Dmax 0.005	0.1587	**Yes**
Middle Medieval	0.0722	Dmax 0.05	0.3205	No
Late Medieval	0.0413	Dmax 0.05	0.1188	No

6.7.1.4 Caries Prevalence.

6.7.1.4.1 Teeth from Adults.

The caries prevalence rates in adult teeth for the coastal and inland sites for each period are shown in Table 6.7:8 and Figure 6.7:5. The Early Medieval coastal sites had a lower caries prevalence rate (3.5%) than did the inland sites (6.0%). The two groups were significantly different from each other at the 0.1% level ($X^2 = 73.4574$, $p<0.001$, d.f. = 1). The caries prevalence rate for the Middle Medieval period was slightly higher in the coastal group (10.0%) than in the inland group (9.1%), but this difference was not statistically significant ($X^2 = 0.5975$, $p>0.05$, d.f. = 1). In contrast, in the Late Medieval period a higher prevalence rate in the adult teeth was seen in the coastal sample (8.9%) than the inland sample (7.4%), and these two rates were significantly different from each other ($X^2 = 34.0165$, $p<0.001$, d.f. = 1).

Table 6.7:8 Caries prevalence in coastal and inland sites - Early, Middle and Late Medieval periods.

Coastal / Inland	Medieval Period	Teeth from Adults			Males			Females		
		C	P	%	C	P	%	C	P	%
Coastal	Early	313	9,056	3.5%	103	3,067	3.4%	90	2,935	3.1%
	Middle	68	680	10.0%	43	285	15.1%	22	341	6.5%
	Late	2,303	25,742	8.9%	869	9,235	9.4%	497	4,806	10.3%
Inland	Early	859	14,414	6.0%	286	5,673	5.0%	336	6,017	5.6%
	Middle	952	10,442	9.1%	184	4,030	4.6%	183	3,015	6.1%
	Late	1,274	17,301	7.4%	488	4,927	9.9%	364	2,703	13.5%

C = With Caries; **P** = Number of teeth present.
See **Appendix 14** for source data for each category.

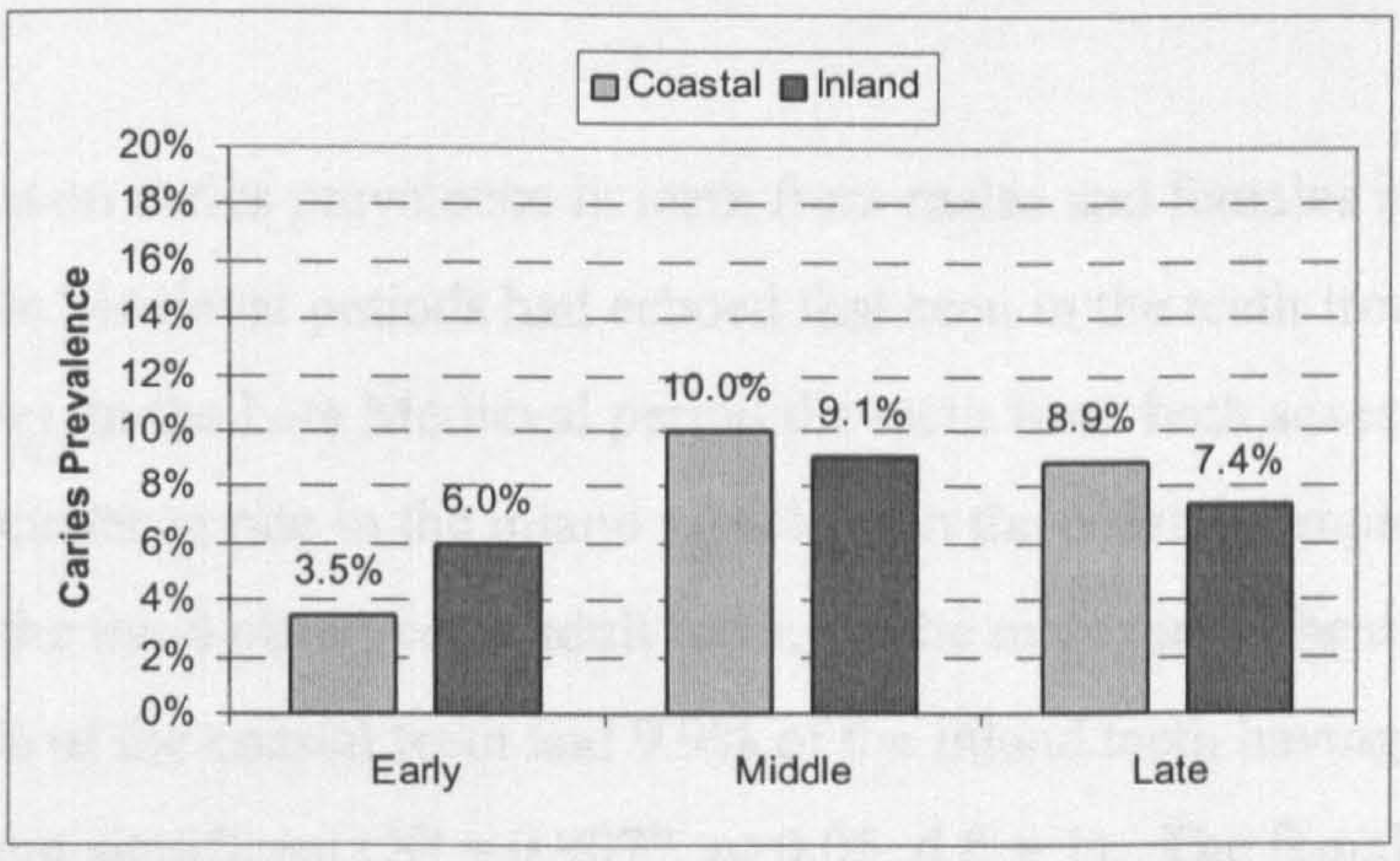

Figure 6.7:5 Caries prevalence in adult teeth in coastal and inland sites - Early, Middle and Late Medieval periods.

For both coastal and inland samples the overall pattern of caries prevalence described in Section 6.3.1.4.1 was maintained (compare Figure 6.7:5 With Figure 6.6:3). The lowest caries prevalence was seen in the Early Medieval sample, with the highest being in the Middle Medieval group. The caries prevalence of the Late Medieval samples was closer to those of the Middle Medieval period.

6.7.1.4.2 Teeth from Adult Male and Female Subdivisions.

In the Early Medieval period the caries prevalence rate in teeth from both males and females was lower in the coastal sample (Male = 3.4%, Female = 3.1%) than in the inland sample (Male = 5.0%, Female = 5.6%; see Table 6.7:8 and Figure 6.7:6), and this difference was statistically significant for both sexes (see Table 6.7:9). The difference between the caries prevalence rates in neither the coastal nor inland sample was significant (coastal: $X^2 = 0.4106$, $p>0.05$, d.f. = 1, inland: $X^2 = 1.7075$, $p>0.05$, d.f. = 1).

The caries prevalence in both male and female teeth was higher in the coastal (Male = 15.1%, Female = 6.5%) than the inland sample (Male = 4.6%, Female = 6.1%) for the Middle Medieval period. The difference in caries prevalence between the inland and coastal male teeth was particularly striking, with 15.5% of the coastal male teeth being carious compared to 4.6% of the inland male teeth, and this difference was statistically significant ($X^2 = 59.1272$, $p<0.001$, d.f. = 1). The difference between the coastal and inland female teeth was small (0.4%) and not significant ($X^2 = 0.0779$, $p>0.05$, d.f. = 1).

Whereas the data on caries prevalence in teeth from males and females in both the Early and Middle Medieval periods had echoed that seen in the teeth from adults (described above), in the Late Medieval period the teeth from both sexes exhibited a higher caries prevalence rate in the inland sample than the coastal sample, which was the opposite of the trend observed in adult teeth. In the male teeth, the difference was small, with 9.4% of the coastal teeth and 9.9% of the inland teeth having caries. This difference was not significant ($X^2 = 0.9077$, $p>0.05$, d.f. = 1). The female teeth, however, had a significantly higher caries prevalence rate in the inland sample (13.5%) than the coastal sample (10.3%; $X^2 = 16.6454$, $p<0.001$, d.f. = 1). In both coastal and inland samples the female teeth had a higher caries prevalence rate than the male. This difference was small and not significant for the coastal sample ($X^2 = 3.1223$, $p>0.05$, d.f. = 1), but was significant in the inland sample ($X^2 = 22.3243$, $p<0.001$, d.f. = 1).

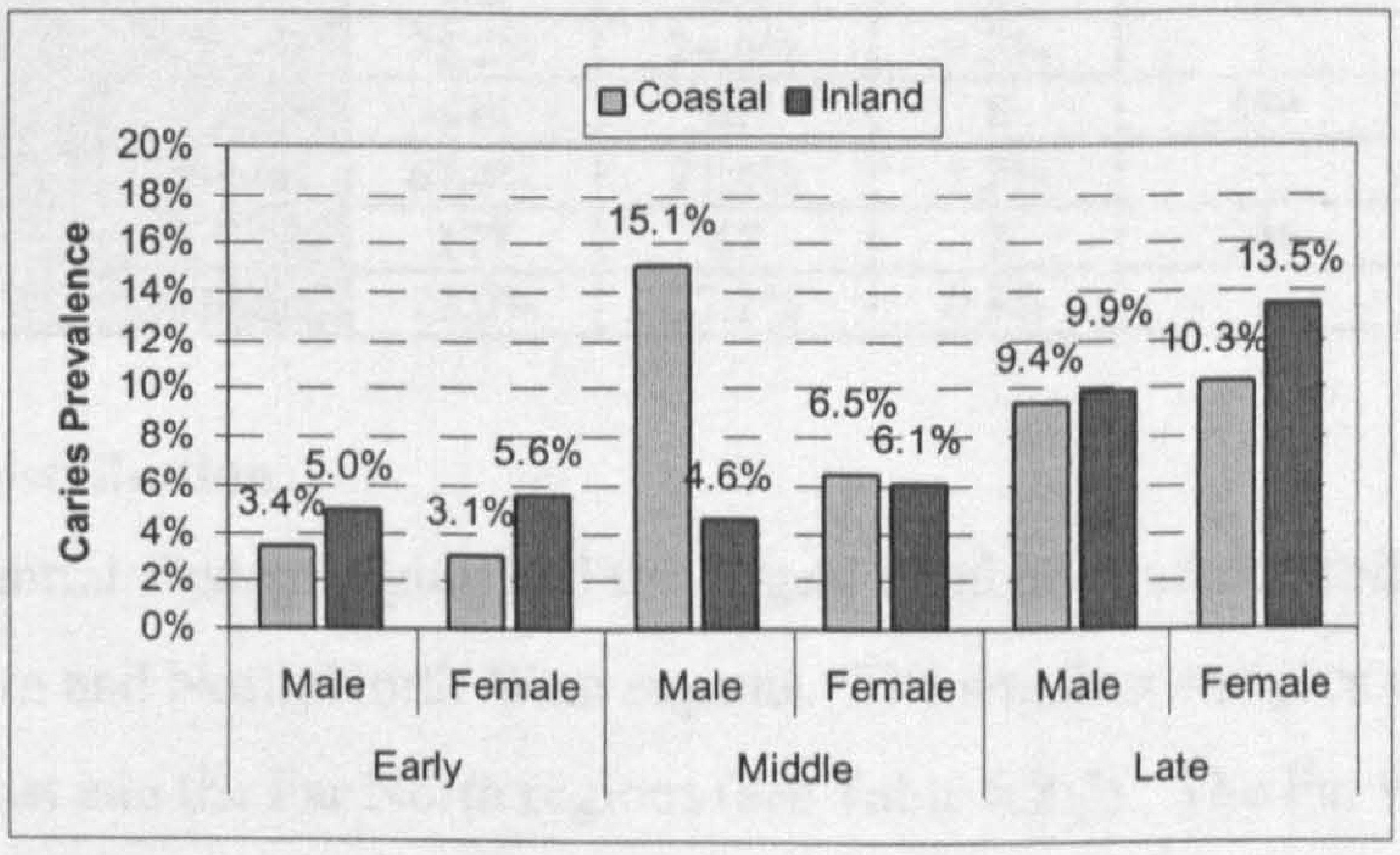

Figure 6.7:6 Caries prevalence in male and female teeth in coastal and inland sites - Early, Middle and Late Medieval periods.

Table 6.7:9 Comparison of caries prevalence in male and female teeth between coastal and inland sites - Early, Middle and Late Medieval periods: chi-square values and significance level.

Coastal / Inland Compared	Male Teeth			Female Teeth		
	X^2	d.f.	p	X^2	d.f.	p
Early Medieval	13.2607	1	p<0.001	27.5915	1	p>0.001
Middle Medieval	59.1272	1	p<0.001	0.0779	1	p>0.05
Late Medieval	0.9077	1	p>0.05	16.6454	1	p<0.001

d.f. = degrees of freedom.

6.8 Regional Division.

6.8.1 Early Medieval Period: Regional Variation.

6.8.1.1 Proportions of Adults and Subadults.

The largest samples came from the Central Southern and Eastern/Central Eastern sites, followed by the Far North and North/North West sites, with the smallest sample provided by the two sites in the South East (see Table 6.8:1). The proportion of adults within each group ranged from 65.7% (North/North West) to 75.2% (Eastern/Central Eastern).

Table 6.8:1 Number of adult, subadult and unaged individuals in the regions - Early Medieval period.

Region: Early Medieval Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Far North		334	155	0	489
	%Total	68.3%	31.7%	0.0%	-
North/ North West		302	158	0	460
	%Total	65.7%	34.3%	0.0%	-
Eastern/ Central Eastern		482	158	1	641
	%Total	75.2%	24.6%	0.2%	-
Central Southern		444	207	8	659
	%Total	67.4%	31.4%	1.2%	-
South East		177	67	2	246
	%Total	72.0%	27.2%	0.8%	-

6.8.1.2 Sex Distribution.

The Eastern/Central Eastern region had the largest number of adults, followed by the Central Southern and North/North West regions. The smallest samples were provided by the South East and the Far North regions (see Table 6.8:2). The Far North and North/North West samples had the highest proportion of unsexed adults.

Table 6.8:2 Number and percentage of males, females and unsexed adults in the regions - Early Medieval period.

Region: Early Medieval period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Far North		52	52	34	104	138
	%Total Adults	37.7%	37.7%	24.6%	75.4%	-
	%Sexed Adults	50.0%	50.0%	-	-	-
North/ North West		104	104	94	208	302
	%Total Adults	34.4%	34.4%	31.1%	68.9%	-
	%Sexed Adults	50.0%	50.0%	-	-	-
Eastern/ Central Eastern		219	188	75	407	482
	%Total Adults	45.4%	39.0%	15.6%	84.4%	-
	%Sexed Adults	53.8%	46.2%	-	-	-
Central Southern		145	183	27	328	355
	%Total Adults	40.8%	51.5%	7.6%	92.4%	-
	%Sexed Adults	44.2%	55.8%	-	-	-
South East		89	77	11	166	177
	%Total Adults	50.3%	43.5%	6.2%	93.8%	-
	%Sexed Adults	53.6%	46.4%	-	-	-

Table 6.8:3 Results of chi-square test comparing the proportions of males and females against an expected equal distribution in the regions - Early Medieval period.

Region: Early Medieval Sites		Male	Female	Total Sexed Adults	X^2	d.f.	Significant	p
Far North	O	52	52	104	0.0000	1	No	p>0.05
	E	52	52					
North/ North West	O	104	104	208	0.0000	1	No	p>0.05
	E	104	104					
Eastern/ Central Eastern	O	219	188	407	2.3612	1	No	p>0.05
	E	203.5	203.5					
Central Southern	O	145	183	328	4.4024	1	**Yes**	p<0.05
	E	164	164					
South East	O	89	77	166	0.8675	1	No	p>0.05
	E	83	83					

d.f. = degrees of freedom; **O** = Observed value; **E** = Expected value.

The only region with a sex distribution significantly different from the equal proportions expected was the Central Southern region, which had significantly more females (55.8%) than males (44.2%), (see Table 6.8:2 and Table 6.8:3). The proportions of males and females in the Central Southern sample were significantly different from the Eastern/Central Eastern and South East samples, but not from any other region (see Table 6.8:4). There were no significant differences in terms of sex ratios between the other regions.

Table 6.8:4 Results of chi-square test comparing the proportions of males and females in pairs of regions - Early Medieval period.

Regions Compared: Early Medieval Period		X^2	d.f.	Significant	p
Far North	North/ North West	0.0000	1	No	$p>0.05$
Far North	Eastern/ Central Eastern	0.4823	1	No	$p>0.05$
Far North	Central Southern	1.0681	1	No	$p>0.05$
Far North	South East	0.3348	1	No	$p>0.05$
North/ North West	Eastern/ Central Eastern	0.8006	1	No	$p>0.05$
North/ North West	Central Southern	1.7170	1	No	$p>0.05$
North/ North West	South East	0.4829	1	No	$p>0.05$
Eastern/ Central Eastern	Central Southern	6.6976	1	**Yes**	$p<0.01$
Eastern/ Central Eastern	South East	0.0018	1	No	$p>0.05$
Central Southern	South East	3.9123	1	**Yes**	$p<0.05$

d.f. = degrees of freedom.

6.8.1.3 Age Distribution.

6.8.1.3.1 Adults in General.

The two regions with the smallest proportion of Aged Adults were the North/North West (58.3%) and Far North regions (63.5%). The regions with the largest proportion of Aged Adults were the Central Southern (86.5%) and South East regions (81.9%; see Table 6.8:5).

The only regions with significantly different age distributions from each other were the Far North and North/North West (see Table 6.8:6). The North/North West was the only region with a greater proportion of individuals in the two oldest age groups, and it had the largest percentage of adults in the OA group and smallest percentage in the YA group compared to all other regions (see Table 6.8:5 and Figure 6.8:1). In contrast, the Far North sample had the smallest proportion of individuals in the two oldest groups, and, like the South East sample, nearly a third of the adults were assigned to the YA category. The adults in the Eastern/Central Eastern and Central Southern regions were more evenly distributed between the age categories, with roughly a quarter in each.

Table 6.8:5 Number and percentage of adults in each age category in the regions - Early Medieval period.

Regions: Early Medieval Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Far North	64	61	43	44	212	122	334
	30.2%	28.8%	20.3%	20.8%	63.5%	36.5%	
	125		87				100%
	59.0%		41.0%				
North/ North-West	30	47	45	54	176	126	302
	17.0%	26.7%	25.6%	30.7%	58.3%	41.7%	
	77		99				100%
	43.8%		56.3%				
Eastern/ Central Eastern	92	95	92	89	368	114	482
	25.0%	25.8%	25.0%	24.2%	76.3%	23.7%	
	187		181				100%
	50.8%		49.2%				
Central Southern	98	109	82	95	384	60	444
	25.5%	28.4%	21.4%	24.7%	86.5%	13.5%	
	207		177				100%
	53.9%		46.1%				
South East	45	37	28	35	145	32	177
	31.0%	25.5%	19.3%	24.1%	81.9%	18.1%	
	82		63				100%
	56.6%		43.4%				
Total	329	349	290	317	1285	454	1739
	25.6%	27.2%	22.6%	24.7%	73.9%	26.1%	
	678		607				100%
	52.8%		47.2%				

Table 6.8:6 Results of Kolmogorov-Smirnov tests comparing adult age distributions between pairs of regions - Early Medieval period.

Regions Compared: Early Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
Far North / (North/ North West)	0.1521	Dmax 0.025	0.1509	**Yes**
Far North / (Eastern/ Central Eastern)	0.0815	Dmax 0.05	0.1173	No
Far North / Central Southern	0.0506	Dmax 0.05	0.1164	No
Far North / South East	0.0338	Dmax 0.05	0.1466	No
(North/ North West) / (Eastern/ Central Eastern)	0.0795	Dmax 0.05	0.1246	No
(North/ North West) / Central Southern	0.1016	Dmax 0.05	0.1238	No
(North/ North West) / South East	0.1398	Dmax 0.05	0.1525	No
(Eastern/ Central Eastern)/ Central Southern	0.0309	Dmax 0.05	0.0992	No
(Eastern/ Central Eastern)/ South East	0.0603	Dmax 0.05	0.1334	No
Central Southern / South East	0.0551	Dmax 0.05	0.1326	No

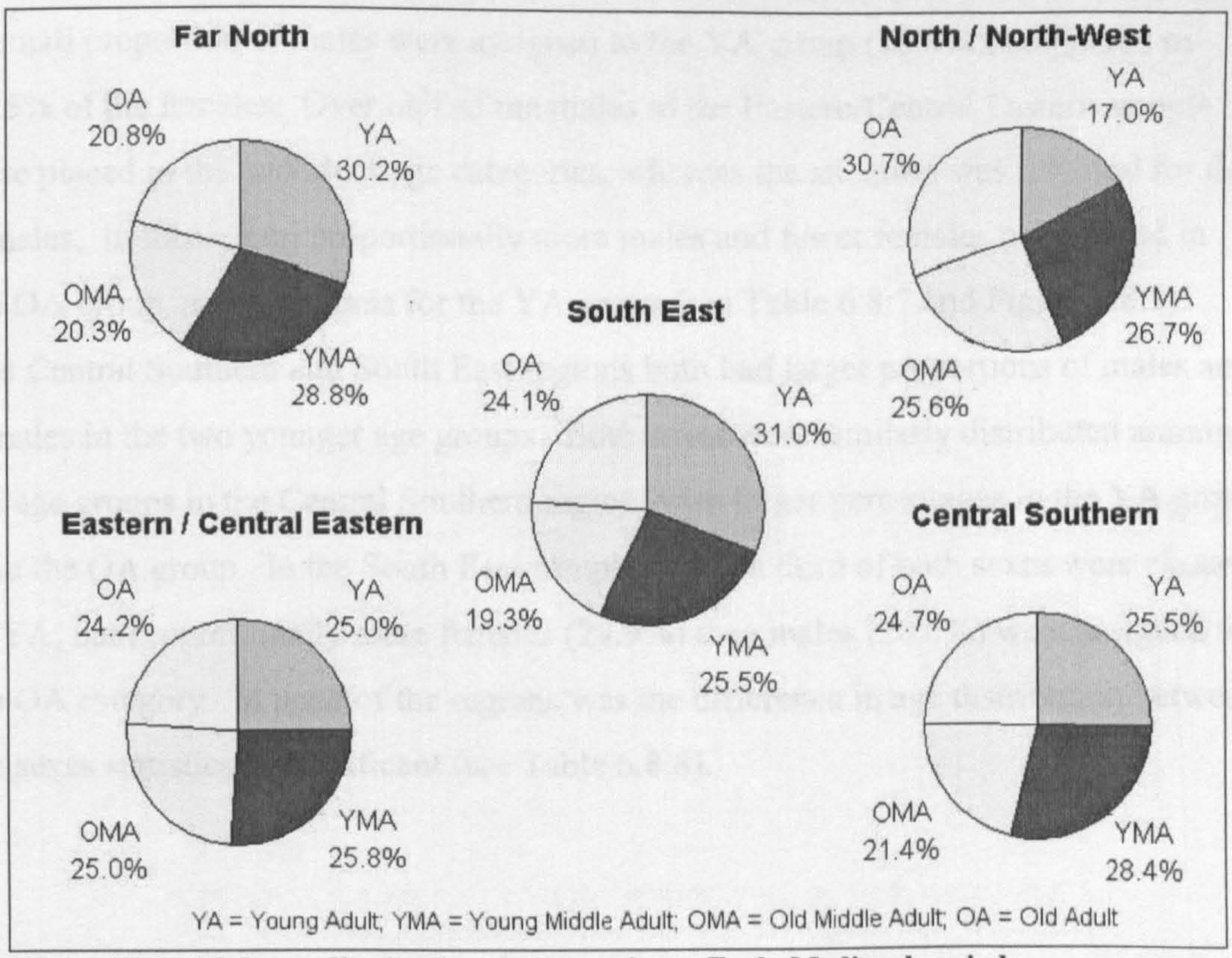

Figure 6.8:1 Adult age distributions in the regions - Early Medieval period.

6.8.1.3.2 Adults: Male and Female Subdivisions.

In the majority of regions over 70% of males and females had been aged, with the exception of the Far North, where less than half the males had been aged (44.2%) and the proportion of aged females was also low (59.6%; see Table 6.8:7). In four of the regions, a higher proportion of females than males had been aged, the exception being the Central Southern region. The proportion of Aged Adults of both sexes was higher than the proportion of Aged Adults in general in the North/North West and Eastern/Central Eastern samples. The proportion was lower for both sexes in the Far North. The proportion of aged males was higher and the proportion of aged females was lower in the Central Southern samples whilst the opposite was true for the South East samples (compare Table 6.8:7 with Table 6.8:5).

In the Far North region a large proportion of both males and females were placed in the two oldest age groups, particularly the OA category, with small percentages, especially males, in the YA group (see Table 6.8:7 and Figure 6.8:2). The North/North West region also had a larger proportion of males and females in the two older age groups, with around a third of both sexes being placed in the OA category. A small proportion of males were assigned to the YA group (10.8%), compared to 22.5% of the females. Over half of the males in the Eastern/Central Eastern sample were placed in the two older age categories, whereas the situation was reversed for the females. In this region proportionally more males and fewer females were found in the OA group, and vice versa for the YA group (see Table 6.8:7 and Figure 6.8:2). The Central Southern and South East regions both had larger proportions of males and females in the two younger age groups. Both sexes were similarly distributed amongst the age groups in the Central Southern region, with larger percentages in the YA group than the OA group. In the South East sample nearly a third of both sexes were classed as YA, but proportionally more females (29.9%) than males (20.0%) were assigned to the OA category. In none of the regions was the difference in age distribution between the sexes statistically significant (see Table 6.8:8).

Table 6.8:7 Number and percentage of males and females in each age category in the regions - Early Medieval period.

Regions: Early Medieval Period		Aged Adults (% Total Aged): Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Far North	Male	2	5	5	11	23	29	52
		8.7%	21.7%	21.7%	47.8%	44.2%	55.8%	
		7		16				100%
		30.4%		69.6%				
	Female	4	4	6	17	31	21	52
		12.9%	12.9%	19.4%	54.8%	59.6%	40.4%	
		8		23				100%
		25.8%		74.2%				
North/ North West	Male	8	24	18	24	74	30	104
		10.8%	32.4%	24.3%	32.4%	71.2%	28.8%	
		32		42				100%
		43.2%		56.8%				
	Female	20	18	24	27	89	15	104
		22.5%	20.2%	27.0%	30.3%	85.6%	14.4%	
		38		51				100%
		42.7%		57.3%				
Eastern/ Central Eastern	Male	36	42	54	49	181	38	219
		19.9%	23.2%	29.8%	27.1%	82.6%	17.4%	
		78		103				100%
		43.1%		56.9%				
	Female	44	41	37	37	159	29	188
		27.7%	25.8%	23.3%	23.3%	84.6%	15.4%	
		85		74				100%
		53.5%		46.5%				
Central Southern	Male	32	41	31	27	131	14	145
		24.4%	31.3%	23.7%	20.6%	90.3%	9.7%	
		73		58				100%
		55.7%		44.3%				
	Female	42	46	30	34	152	31	183
		27.6%	30.3%	19.7%	22.4%	83.1%	16.9%	
		88		64				100%
		57.9%		42.1%				
South East	Male	22	18	16	14	70	19	89
		31.4%	25.7%	22.9%	20.0%	78.7%	21.3%	
		40		30				100%
		57.1%		42.9%				
	Female	20	16	11	20	67	10	77
		29.9%	23.9%	16.4%	29.9%	87.0%	13.0%	
		36		31				100%
		53.7%		46.3%				
Totals	Male	100	130	124	125	479	130	609
		20.9%	27.1%	25.9%	26.1%	78.7%	21.3%	
		230		249				100%
		48.0%		52.0%				
	Female	130	125	108	135	498	106	604
		26.1%	25.1%	21.7%	27.1%	82.5%	17.5%	
		255		243				100%
		51.2%		48.8%				

The two male age distributions that appeared most different were those of the Far North and South East regions, yet even these two samples were not found to be significantly different from each other (see Table 6.8:9), possibly due to the small sample size. Whereas none of the male age distributions were found to be significantly different between regions, the female age distribution of the Far North sample was significantly different from that of the Eastern/Central Eastern and Central Southern samples (see Table 6.8:9). Three-quarters of the Far North females were assigned to the two oldest age groups, and only 12.9% to the YA category. This contrasted with the Eastern/Central Eastern and Central Southern regions, where almost 28% of each sets of females were classed as YA and less than half were assigned to the two older age groups (see Table 6.8:7 and Figure 6.8:2).

Table 6.8:8 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within the regions - Early Medieval period.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Far North	0.0701	Dmax 0.05	0.3743	No
North/ North West	0.1166	Dmax 0.05	0.2140	No
Eastern/ Central Eastern	0.1037	Dmax 0.05	0.1478	No
Central Southern	0.0320	Dmax 0.05	0.1621	No
South East	0.0985	Dmax 0.05	0.2324	No

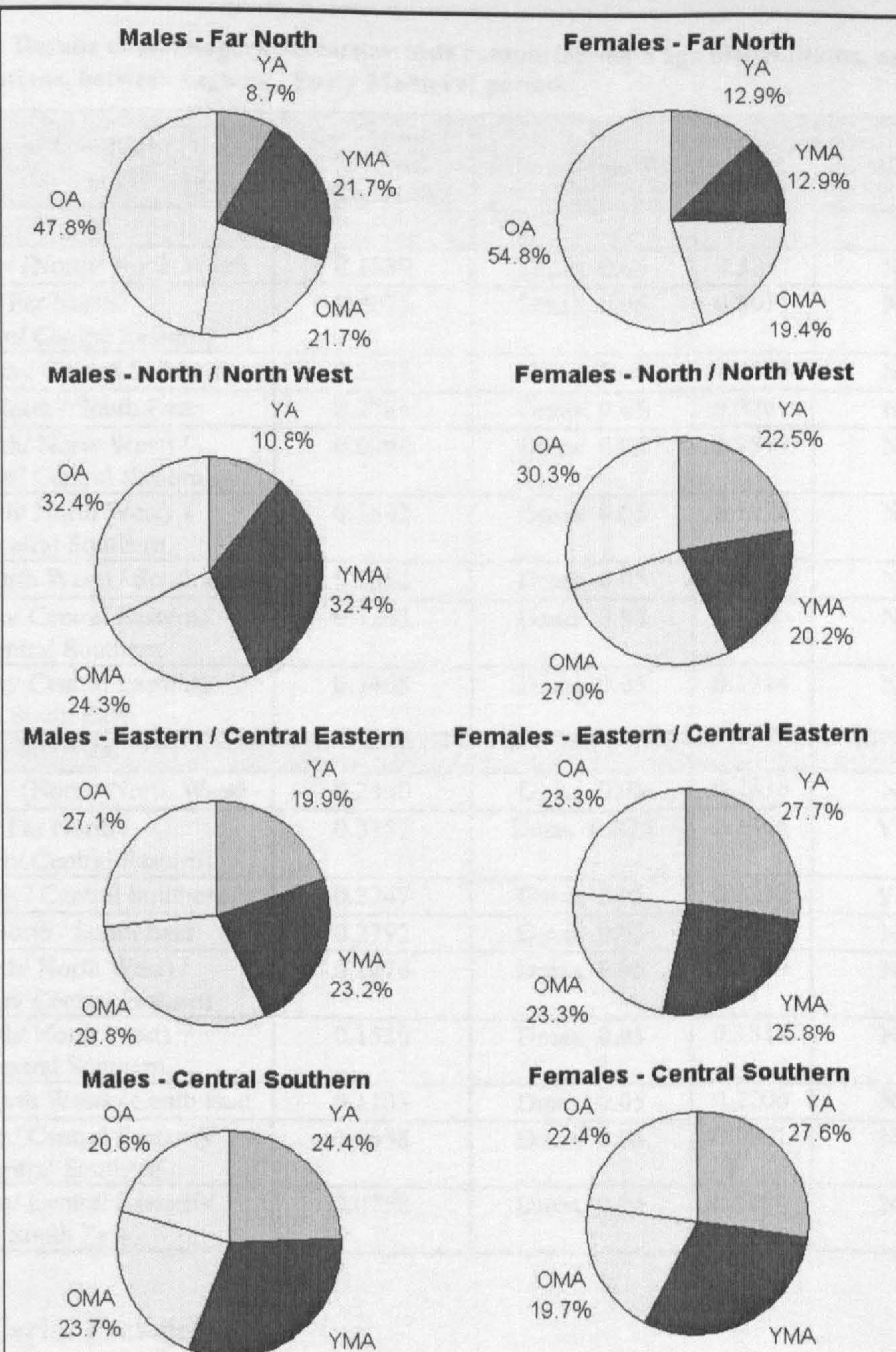

Figure 6.8:2 Male and female age distributions in the regions - Early Medieval period.

Table 6.8:9 Results of Kolmogorov-Smirnov tests comparing male age distributions, and female age distributions, between regions - Early Medieval period.

Regions Compared: Early Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
Males:				
Far North / (North/ North West)	0.1539	Dmax 0.05	0.3247	No
Far North / (Eastern/ Central Eastern)	0.2075	Dmax 0.05	0.3011	No
Far North / Central Southern	0.2722	Dmax 0.05	0.3075	No
Far North / South East	0.2783	Dmax 0.05	0.3269	No
(North/ North West) / (Eastern/ Central Eastern)	0.0908	Dmax 0.05	0.1877	No
(North/ North West) / Central Southern	0.1362	Dmax 0.05	0.1978	No
(North/ North West) / South East	0.2062	Dmax 0.05	0.2268	No
(Eastern/ Central Eastern)/ Central Southern	0.1263	Dmax 0.05	0.1560	No
(Eastern/ Central Eastern)/ South East	0.1405	Dmax 0.05	0.1914	No
Females:				
Far North / (North/ North West)	0.2450	Dmax 0.05	0.2836	No
Far North / (Eastern/ Central Eastern)	0.3157	Dmax 0.025	0.2906	**Yes**
Far North / Central Southern	0.3247	Dmax 0.01	0.3212	**Yes**
Far North / South East	0.2792	Dmax 0.05	0.2954	No
(North/ North West) / (Eastern/ Central Eastern)	0.1076	Dmax 0.05	0.1800	No
(North/ North West) / Central Southern	0.1520	Dmax 0.05	0.1815	No
(North/ North West) / South East	0.1103	Dmax 0.05	0.2200	No
(Eastern/ Central Eastern)/ Central Southern	0.0658	Dmax 0.05	0.1981	No
(Eastern/ Central Eastern)/ South East	0.0758	Dmax 0.05	0.1994	No

6.8.1.4 Caries Prevalence.

6.8.1.4.1 Teeth from Adults.

The two Early Medieval regions with the lowest caries prevalence in teeth from adults were the Eastern/Central Eastern (2.9%) and Far North (3.5%) regions (see Table 6.8:10 and Figure 6.8:3). The prevalence rates for these two regions were not significantly different from each other, but they were different from the other three regions (see Table 6.8:11). The Central Southern region had the highest caries prevalence (6.5%), closely followed by the North/North West region (6.2%), and again, they were not significantly different from each other (see Table 6.8:11). Although the caries prevalence in the South East sample (5.1%) was not significantly different from the North/North West region, it was significantly different from the Central Southern region (see Table 6.8:11).

Table 6.8:10 Caries prevalence in the regions - Early Medieval period.

Regions: Early Medieval Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Far North	129	3,643	3.5%	5	473	1.1%	8	375	2.1%
North/ North West	176	2,826	6.2%	76	1,175	6.5%	95	1,487	6.4%
Eastern/ Central Eastern	167	5,843	2.9%	83	3,067	2.7%	75	2,475	3.0%
Central Southern	592	9,058	6.5%	167	2,928	5.7%	198	3,727	5.3%
South East	108	2,100	5.1%	58	1,097	5.3%	50	88	5.6%

C = With Caries; P = Number of teeth present.
See **Appendix 15** for source data for each category.

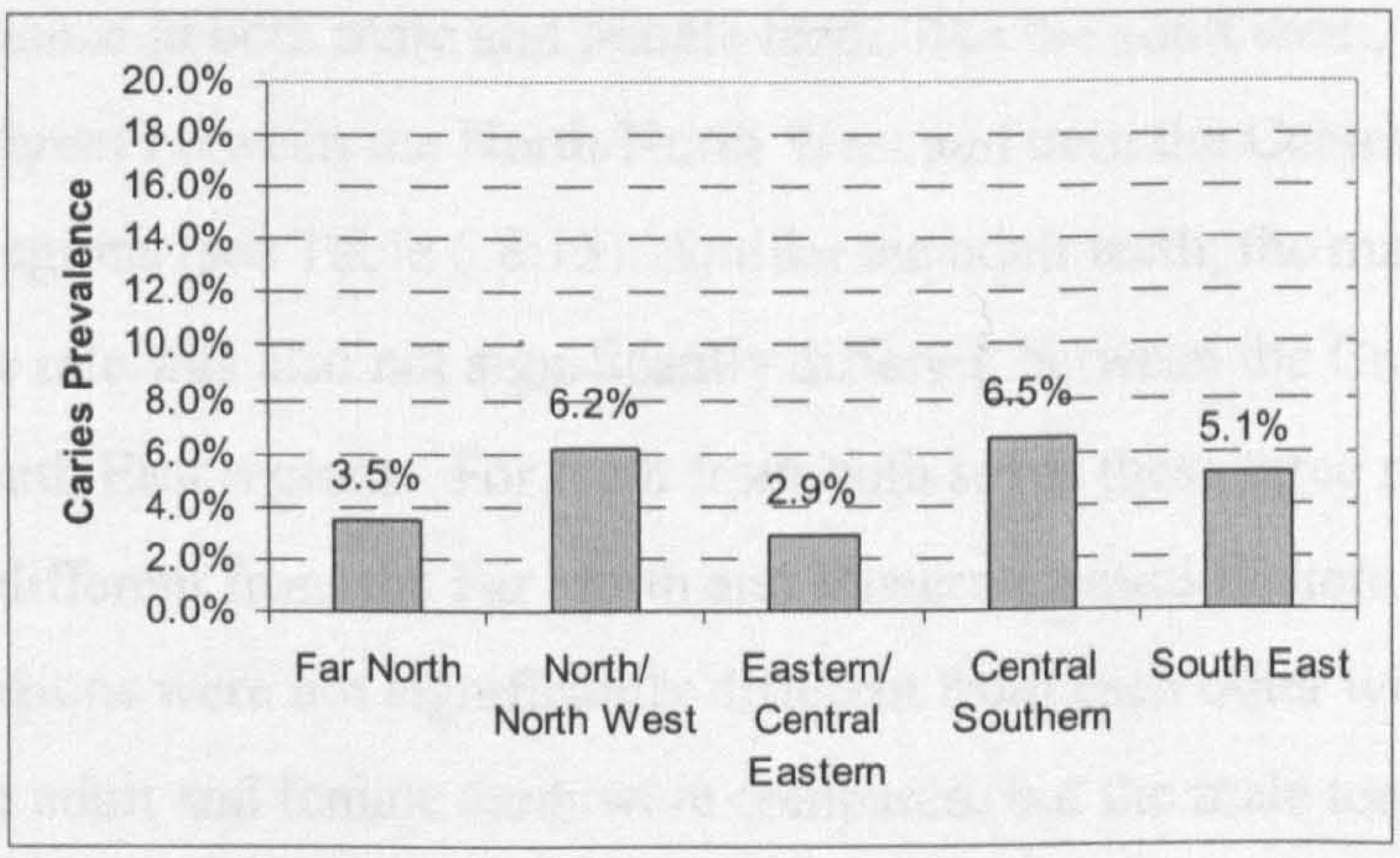

Figure 6.8:3 Caries prevalence in adult teeth in the regions - Early Medieval period.

Table 6.8:11 Results of chi-square test comparing caries prevalence (adult teeth) in pairs of regions - Early Medieval period.

Regions Compared: Early Medieval Period		X^2	d.f.	Significant	p
Far North	**North/ North West**	25.5736	1	**Yes**	p<0.001
Far North	**Eastern/ Central Eastern**	3.4618	1	No	p>0.05
Far North	**Central Southern**	43.5132	1	**Yes**	p<0.001
Far North	**South East**	8.6389	1	**Yes**	p<0.005
North/ North West	**Eastern/ Central Eastern**	56.9174	1	**Yes**	p<0.001
North/ North West	**Central Southern**	0.3375	1	No	p>0.05
North/ North West	**South East**	2.6106	1	No	p>0.05
Eastern/ Central Eastern	**Central Southern**	99.3677	1	**Yes**	p<0.001
Eastern/ Central Eastern	**South East**	24.1267	1	**Yes**	p<0.001
Central Southern	**South East**	5.6243	1	**Yes**	p<0.025

d.f. = degrees of freedom.

6.8.1.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rates in teeth from males and females are shown in Table 6.8:10 and Figure 6.8:4. In all five regions the similarity in caries prevalence between the male and female teeth is apparent, and in none of the regions was the difference significant (see Table 6.8:12). Overall the pattern was similar to that for the adult teeth. For teeth from both sexes the two regions with the lowest prevalence rate were the Far North and Eastern/Central Eastern, although this time the Far North region was lowest. For both male and female teeth the highest prevalence rates were observed in the North/North West region.

The caries prevalence in both male and female teeth, like the adult teeth, was not significantly different between the North/North West and both the Central Southern and South East regions (see Table 6.8:13). Unlike the adult teeth, the male and female caries prevalence rate was also not significantly different between the Central Southern and South East regions. For teeth from both sexes these three regions were all significantly different from the Far North and Eastern/Central Eastern samples. The latter two regions were not significantly different from each other where caries prevalence in the adult and female teeth were compared, but the male teeth caries prevalence was significantly different between the two regions (see Table 6.8:13).

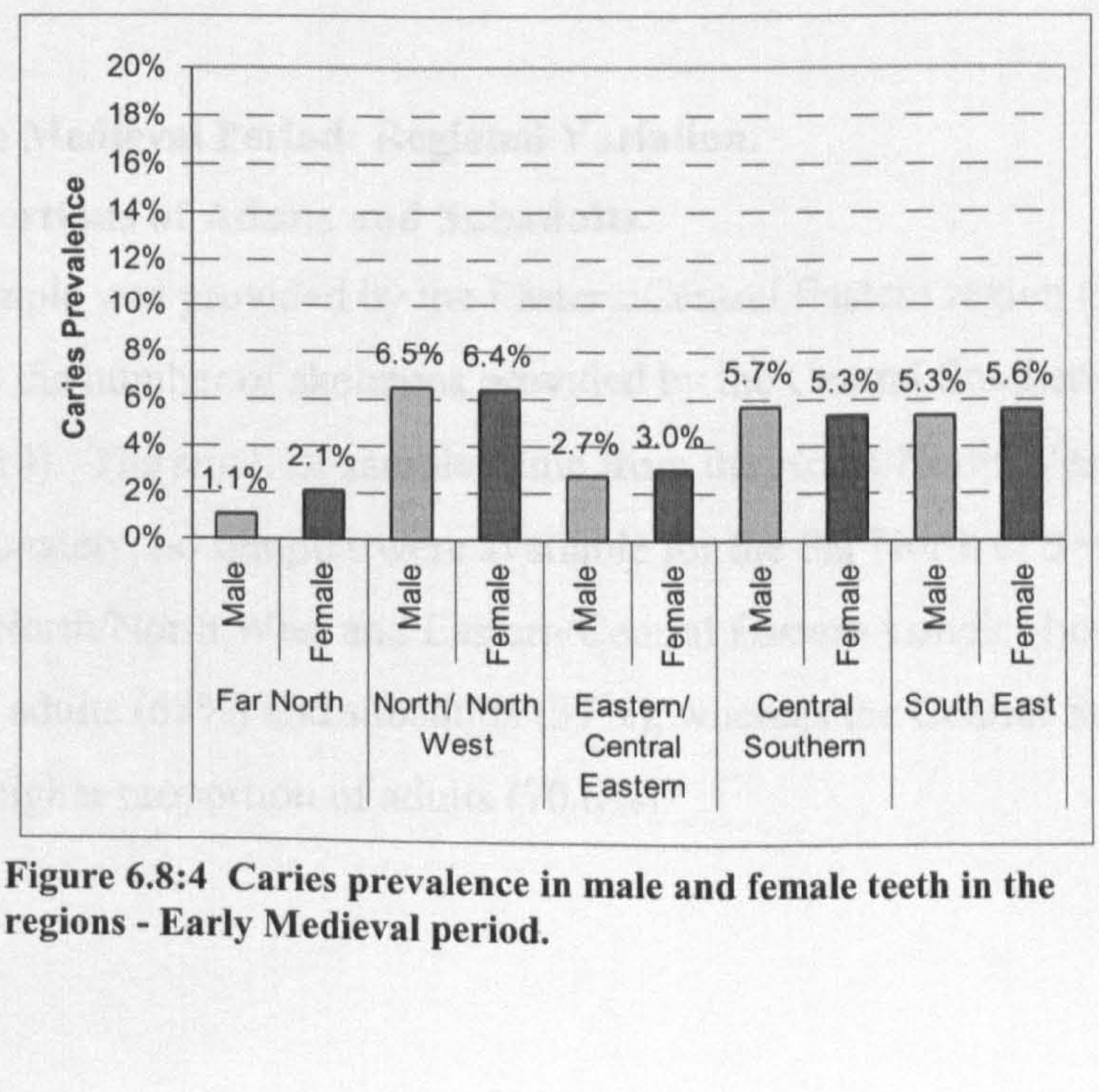

Figure 6.8:4 Caries prevalence in male and female teeth in the regions - Early Medieval period.

Table 6.8:12 Results of chi-square test comparing caries prevalence between male and female teeth within each region - Early Medieval period.

Region: Early Medieval Period	X^2	d.f.	Significant	p
Far North	1.6050	1	No	p>0.05
North/ North West	0.0069	1	No	p>0.05
Eastern/ Central Eastern	0.5194	1	No	p>0.05
Central Southern	0.4835	1	No	p>0.05
South East	0.1125	1	No	p>0.05
d.f. = degrees of freedom.				

Table 6.8:13 Comparison of caries prevalence in male and female teeth between regions - Early Medieval period: chi-square values and significance level.

Regions Compared: Early Medieval Period		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Far North	**North/ NorthWest**	21.1280	1	p<0.001	10.3775	1	p<0.005
Far North	**Eastern/ Central Eastern**	4.5977	1	p<0.05	0.9267	1	p>0.05
Far North	**Central Southern**	18.3100	1	p<0.001	7.2202	1	p<0.01
Far North	**South East**	15.3535	1	p<0.001	7.3603	1	p<0.01
North/ North West	**Eastern/ Central Eastern**	33.3235	1	p<0.001	25.5122	1	p<0.001
North/ North West	**Central Southern**	0.8796	1	p>0.05	2.3208	1	p>0.05
North/ North West	**South East**	1.4256	1	p>0.05	0.5574	1	p>0.05
Eastern/ Central Eastern	**Central Southern**	33.6753	1	p<0.001	18.4103	1	p<0.001
Eastern/ Central Eastern	**South East**	16.4517	1	p<0.001	12.3477	1	p<0.001
Central Southern	**South East**	0.2622	1	p>0.05	0.1427	1	p>0.05
d.f. = degrees of freedom.							

6.8.2 Middle Medieval Period: Regional Variation.

6.8.2.1 Proportions of Adults and Subadults.

The largest sample was provided by the Eastern/Central Eastern region (945), which had over triple the number of skeletons provided by the Central Southern region (286; see Table 6.8:14). The smallest sample came from the North/North West region (131). Unfortunately, no samples were available for the Far North or South East regions. The North/North West and Eastern/Central Eastern samples both had similar proportions of adults (63%) and subadults (37%), whereas the Central Southern sample had a higher proportion of adults (70.6%).

Table 6.8:14 Number of adult, subadult and unaged individuals in the regions - Middle Medieval period.

Regions: Middle Medieval Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Far North		-	-	-	-
	%Total	-	-	-	-
North/ North West		83	48	0	131
	%Total	63.4%	36.6%	0.0%	-
Eastern/ Central Eastern		592	351	2	945
	%Total	62.6%	37.1%	0.2%	-
Central Southern		202	84	0	286
	%Total	70.6%	29.4%	0.0%	-
South East		-	-	-	-
	%Total	-	-	-	-

6.8.2.2 Sex Distribution.

Middle Medieval sites providing data on caries prevalence in male and female teeth were located in only two regions: North/North West and Eastern/Central Eastern. The latter provided the largest number of skeletons, but both regional samples had a high proportion of sexed adults at over 90% (see Table 6.8:15). The proportion of males and females in the North/North West sample was not significantly different from the even ratio expected ($X^2 = 2.0864$, $p>0.05$, d.f. = 1). The Eastern/Central Eastern samples did differ significantly from a normal equal distribution at the 5% level, but not the 2.5% level ($X^2 = 4.2453$, $p<0.05$, d.f. = 1). However, there was no significant difference in the proportions of males and females between the two regions ($X^2 = 0.3063$, $p>0.05$, d.f. = 1).

Table 6.8:15 Number and percentage of males, females and unsexed adults in the regions - Middle Medieval period.

Regions: Middle Medieval period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Far North		-	-	-	-	-
	%Total Adults	-	-	-	-	-
	%Sexed Adults	-	-	-	-	-
North/ North West		47	34	2	81	83
	%Total Adults	56.6%	41.0%	2.4%	97.6%	-
	%Sexed Adults	58.0%	42.0%	-	-	-
Eastern/ Central Eastern		261	216	39	477	516
	%Total Adults	50.6%	41.9%	7.6%	92.4%	-
	%Sexed Adults	54.7%	45.3%	-	-	-
Central Southern		-	-	-	-	-
	%Total Adults	-	-	-	-	-
	%Sexed Adults	-	-	-	-	-
South East		-	-	-	-	-
	%Total Adults	-	-	-	-	-
	%Sexed Adults	-	-	-	-	-

6.8.2.3 Age Distribution.

6.8.2.3.1 Adults in General.

There were only two regions where the age distributions could be compared in the Middle Medieval period (see Table 6.8:16 and Figure 6.8:5). The North/North West region had the greatest proportion of Aged Adults (85.5%) compared to the Eastern/Central Eastern region (77.2%), and there was a significant difference between the age distributions of these two regions ($D_{MAXobs} = 0.2078$, $D_{MAX\ 0.025} = 0.1888$). The North/North West sample had a high proportion of individuals in the YA category (45.1%), but only 5.6% in the OA category. The remaining individuals were distributed fairly equally between the middle two age groups. Consequently, the great majority of the individuals in the North/North West sample were in the youngest two age categories (70.4%). In contrast, the Eastern/Central Eastern region had a more even distribution of individuals between the age categories. The category with the smallest number of individuals was still the OA group (17.5%), but there were fewer individuals in the YA category (24.3%), and most individuals were found in the middle two categories (see Table 6.8:16 and Figure 6.8:5).

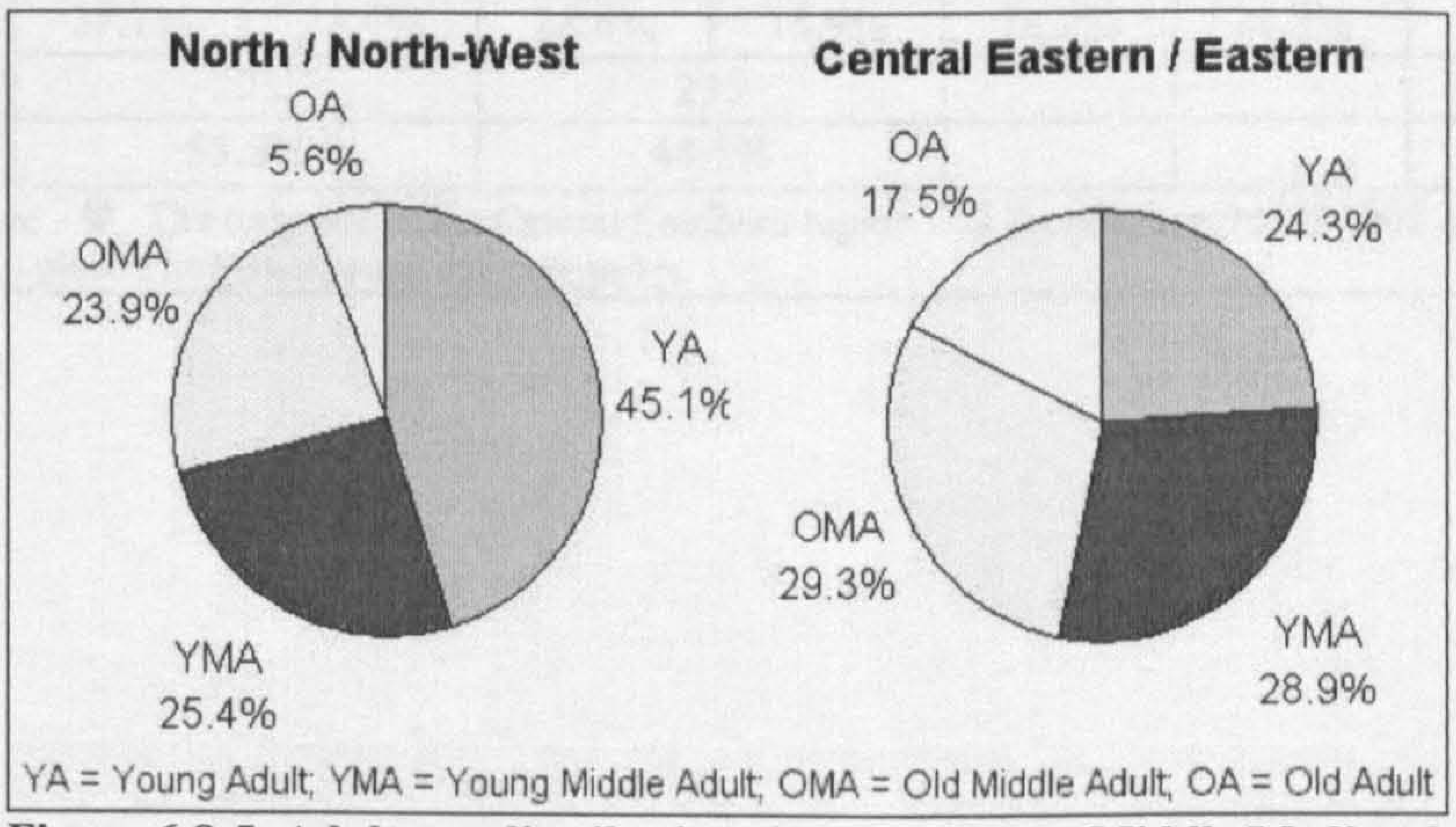

Figure 6.8:5 Adult age distributions in the regions - Middle Medieval period.

Table 6.8:16 Number and percentage of adults in different age categories in the regions - Middle Medieval period.

Regions: Middle Medieval Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Far North	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
	-		-				
	-		-				
North/ North West	32	18	17	4	71	12	83
	45.1%	25.4%	23.9%	5.6%	85.5%	14.5%	
	50		21				100%
	70.4%		29.6%				
Eastern/ Central Eastern	111	132	134	80	457	135	592
	24.3%	28.9%	29.3%	17.5%	77.2%	22.8%	
	243		214				100%
	53.2%		46.8%				
Central Southern	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
							❶
	-		-				
South East	-	-	-	-	-	-	-
	-		-				-
	-		-				-
Total	143	150	151	84	528	147	675
	27.1%	28.4%	28.6%	15.9%	78.2%	21.8%	❶
	293		235				100%
	55.5%		44.5%				

These data exclude - ❶ The only site in the Central Southern region was Trowbridge, but the 202 adults at this site were only placed into two broad age categories.

6.8.2.3.2 Adults: Male and Female Subdivisions.

The proportion of Eastern/Central Eastern Aged Adults of both sexes was higher than the proportion of Aged Adults in general. Whilst the proportion of North/North West aged males was also higher the female sample was lower (compare Table 6.8:17 with Table 6.8:16). Proportionally more males than females could be assigned to an age category

In the North/North West region half the males were placed in the YA category, with 29.5% in the YMA group, leaving only 20.5% in the two older age groups combined (see Table 6.8:17 and Figure 6.8:6). Like the males a fairly high proportion of females were classed as YA and a small proportion were placed in the OA category, but, unlike the males, 42.3% were placed in the OMA age group resulting in 46.2% of the females being in the two older age groups. These differences were not found to be significant (see Table 6.8:18), possibly due to the small sample sizes. In contrast, the age distributions of the males and females were found to be significantly different in the Eastern/Central Eastern region (see Table 6.8:18). A greater percentage of males were found in the two older age groups, whereas the females had proportionally more individuals in the younger age categories (see Table 6.8:17 and Figure 6.8:6). Whereas 20.6% of the males were found in both the OA and YA groups, 12.6% of the females were classed as OA and 30.5% as YA.

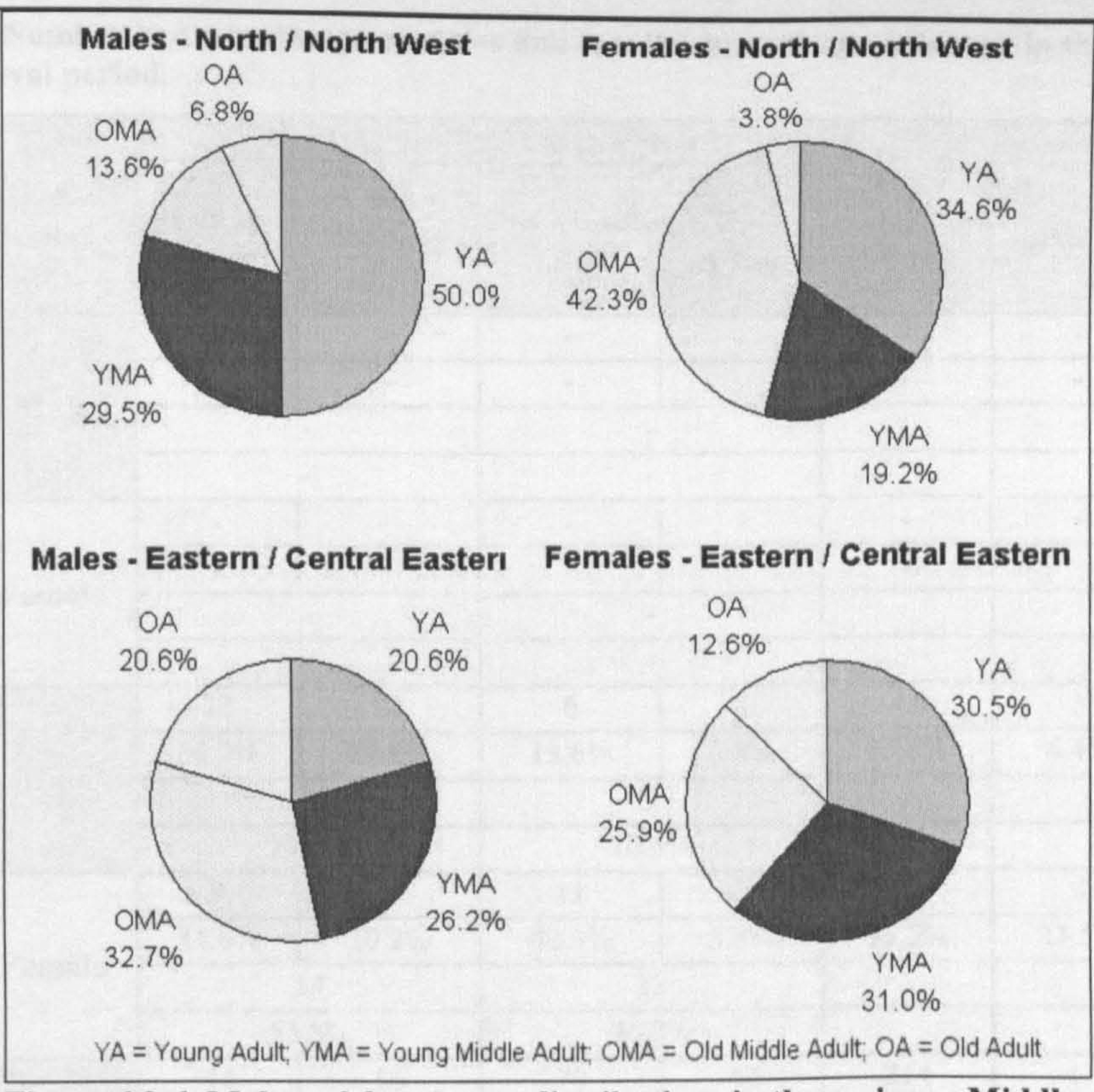

Figure 6.8:6 Male and female age distributions in the regions - Middle Medieval period.

The age distributions of the females in the two regions were not significantly different from each other (see Table 6.8:19). Both had a greater proportion of females in the two younger age groups, although the North/North West females had a higher percentage in the OMA group than the Eastern/Central Eastern females. In contrast, the male age distributions were significantly different (see Table 6.8:19). Of the North/North West males 79.5% were in the two younger age groups, compared to 46.7% of the Eastern/Central Eastern males. Only 6.8% of the former were classed as OA compared to 20.6% of the latter (see Table 6.8:17 and Figure 6.8:6).

Table 6.8:17 Number and percentage of males and females in each age category in the regions - Middle Medieval period.

Regions: Middle Medieval Period		Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Far North	Male	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
	Female	-	-	-	-	-	-	-
			-		-	-	-	-
		-		-				-
		-		-				
North/ North West	Male	22	13	6	3	44	3	47
		50.0%	29.5%	13.6%	6.8%	93.6%	6.4%	
		35		9				100%
		79.5%		20.5%				
	Female	9	5	11	1	26	8	34
		34.6%	19.2%	42.3%	3.8%	76.5%	23.5%	
		14		12				100%
		53.8%		46.2%				
Eastern/ Central Eastern	Male	44	56	70	44	214	47	261
		20.6%	26.2%	32.7%	20.6%	82.0%	18.0%	
		100		114				100%
		46.7%		53.3%				
	Female	53	54	45	22	174	42	216
		30.5%	31.0%	25.9%	12.6%	80.6%	19.4%	
		107		67				100%
		61.5%		38.5%				
Central Southern	Male	-	-	-	-	-	-	-
				-				-
		-		-				
	Female	-	-	-	-	-	-	-
					-	-	-	-
		-		-				-
		-		-				
South East	Male	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
	Female	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
Totals	Male	66	69	76	47	258	50	308
		25.6%	26.7%	29.5%	18.2%	83.8%	16.2%	
		135		123				100%
		52.3%		47.7%				
	Female	62	59	56	23	200	50	250
		31.0%	29.5%	28.0%	11.5%	80.0%	20.0%	
		121		79				100%
		60.5%		39.5%				

Table 6.8:18 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within each region - Middle Medieval period.

Male/Female Compared: Middle Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
North/ North West	0.257	Dmax 0.05	0.3364	No
Eastern/ Central Eastern	0.1477	Dmax 0.05	0.1388	**Yes**

Table 6.8:19 Results of Kolmogorov-Smirnov tests comparing male age distributions, and female age distributions, between pairs of regions - Middle Medieval period.

Regions Compared: Middle Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
Males:				
(North/ North West) / (Eastern/ Central Eastern)	0.3282	Dmax 0.001	0.3228	**Yes**
Females:				
(North/ North West) / (Eastern/ Central Eastern)	0.0880	Dmax 0.05	0.1800	No

6.8.2.4 Caries Prevalence.

6.8.2.4.1 Teeth from Adults.

The region with the highest caries prevalence was the Central Southern region, which, with a rate of 24.3%, was four times greater than the next highest prevalence rate of 6.1%, found in the Eastern/Central Eastern region (see Table 6.8:20 and Figure 6.8:7). Not surprisingly, the Central Southern region was significantly different from both the Eastern/Central Eastern ($X^2 = 601.4913$, $p<0.001$, d.f. = 1) and North/North West ($X^2 = 247.1669$, $p<0.001$, d.f. = 1) regions. The North/North West region had the lowest caries prevalence (4.3%), which was significantly different from the Eastern/Central Eastern sample ($X^2 = 7.0356$, $p<0.01$, d.f. = 1).

Table 6.8:20 Caries prevalence in the regions - Middle Medieval period.

Regions: Middle Medieval Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Far North	-	-	-	-	-	-	-	-	-
North/ North West	60	1,406	4.3%	20	900	2.2%	40	506	7.9%
Eastern/ Central Eastern	466	7,685	6.1%	207	3,415	6.1%	165	2,850	5.8%
Central Southern	494	2,031	24.3%	-	-	-	-	-	-
South East	-	-	-	-	-	-	-	-	-

C = With Caries; **P** = Number of teeth present.
See **Appendix 16** for source data for each category.

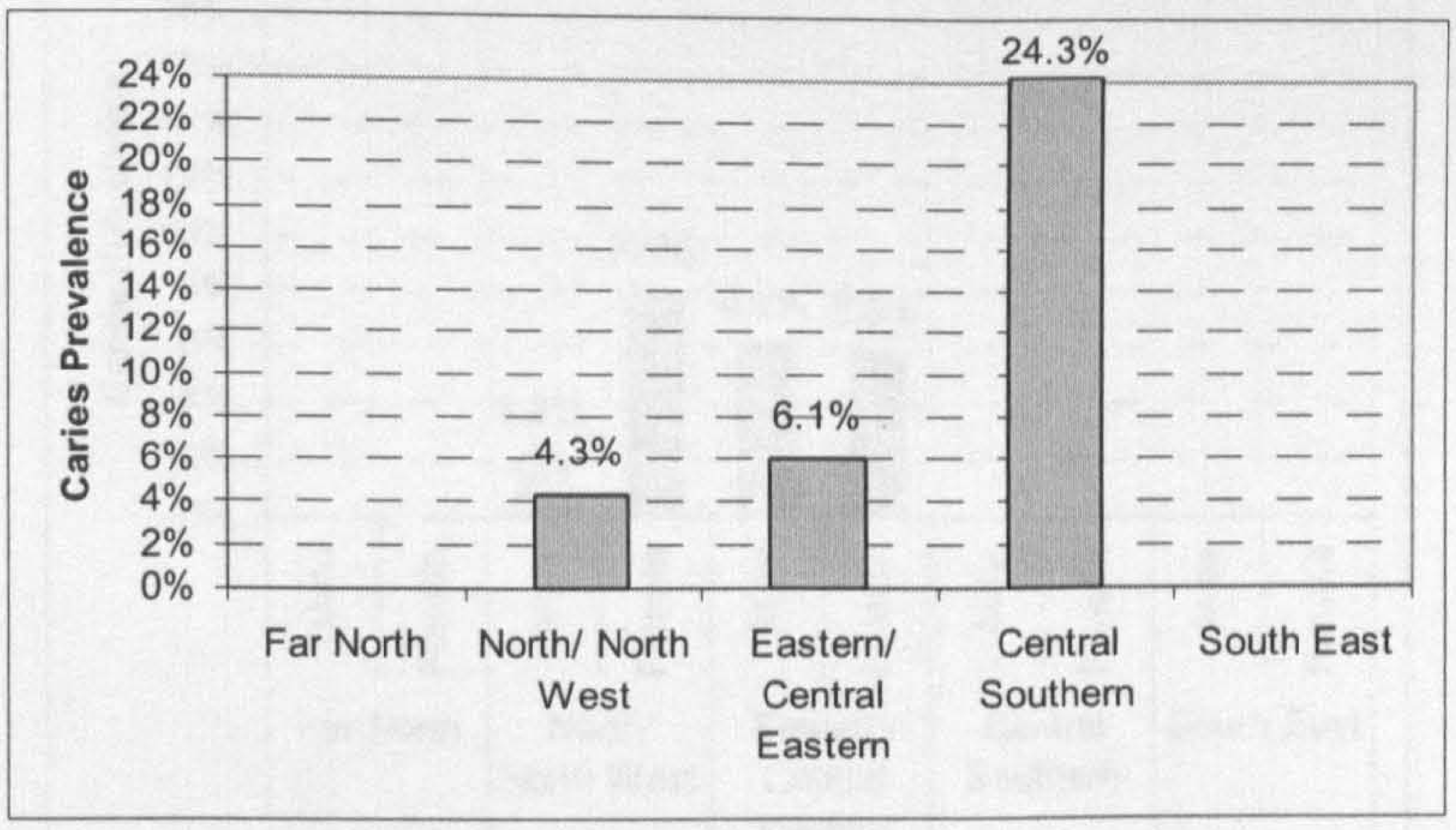

Figure 6.8:7 Caries prevalence in adult teeth in the regions - Middle Medieval period.

6.8.2.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rates for the male and female teeth are shown in Table 6.8:20 and Figure 6.8:8). In the Eastern/Central Eastern region the caries prevalence was similar for male and female teeth, and the difference between them was not significant ($X^2 = 0.2058$, $p>0.05$, d.f. = 1). The female teeth in the North/North West region, however, had a markedly higher caries prevalence rate (7.9%) than the male teeth (2.2%), significant at the 0.1% level ($X^2 = 25.6050$, $p>0.05$, d.f. = 1). The caries prevalence in the female teeth was not significantly different between the two regions ($X^2 = 3.3536$, $p>0.05$, d.f. = 1), but that of the male teeth was ($X^2 = 21.0657$, $p<0.001$, d.f. = 1).

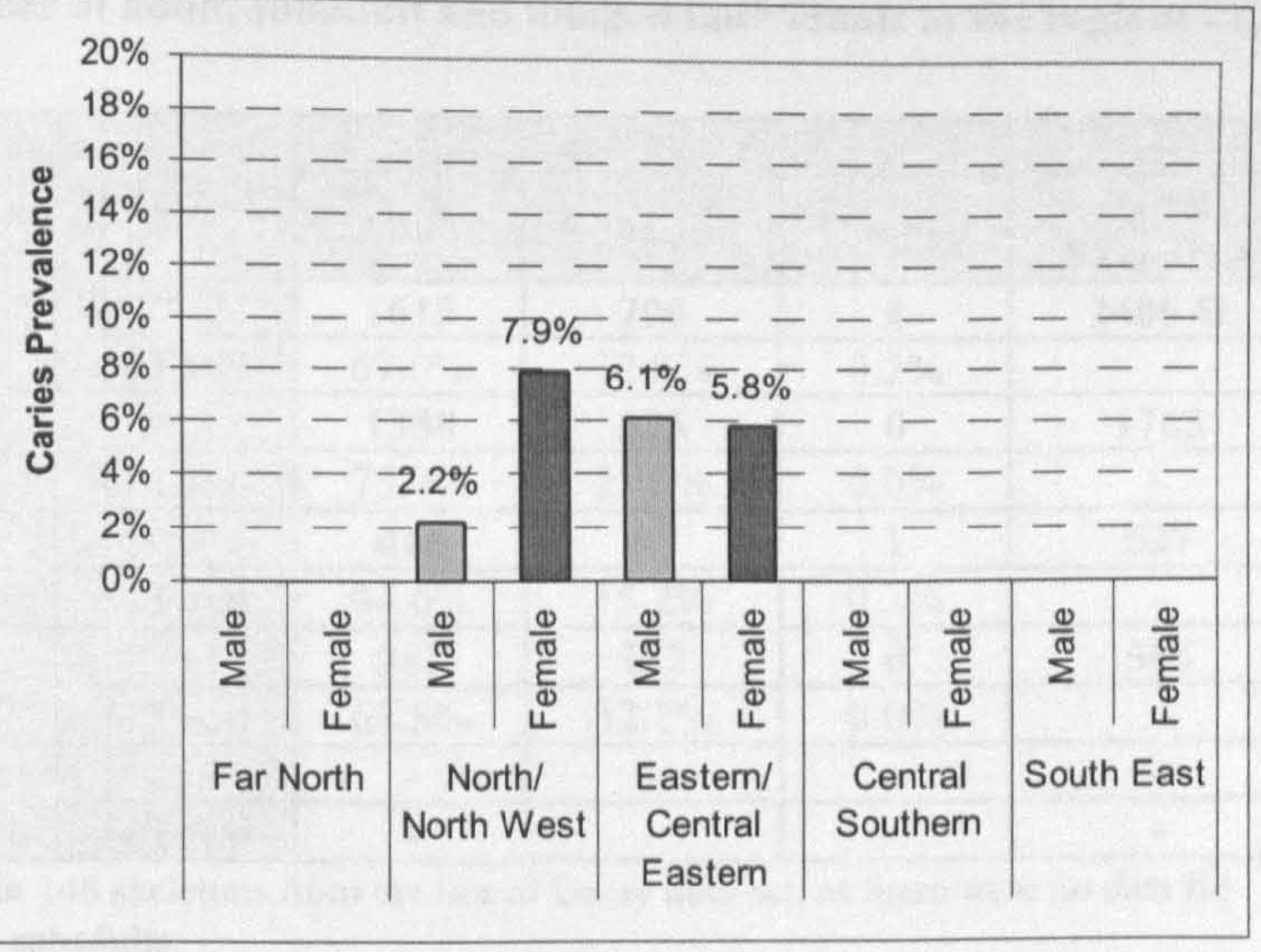

Figure 6.8:8 Caries prevalence in male and female teeth in the regions - Middle Medieval period.

6.8.3 Late Medieval Period: Regional Variation.

6.8.3.1 Proportions of Adults and Subadults.

In marked contrast to the Early Medieval period, the largest samples for the Late Medieval period came from the Far North and North/North West regions, which, between them, had nearly four times as many skeletons as the Central Southern and Eastern/Central Eastern samples put together (see Table 6.8:21 and Table 6.8:1). As for the Middle Medieval period, there were no data-sets available for the South East region. The proportion of adults and subadults in the Far North and Central Southern regions was similar, both having a lower proportion of adults than the North/North West (78.7%) and Eastern/Central Eastern (84.6%) samples.

Table 6.8:21 Number of adult, subadult and unaged individuals in the regions - Late Medieval period.

Regions: Late Medieval Period		Age			
		Adult	Subadult	Unaged	Total Skeletons
Far North		**1615**	**790**	**4**	**2409 ❶**
	%Total	67.0%	32.8%	0.2%	-
North/ North West		**1388**	**375**	**0**	**1763**
	%Total	78.7%	21.3%	0.0%	-
Eastern/ Central Eastern		**446**	**80**	**1**	**527**
	%Total	84.6%	15.2%	0.2%	-
Central Southern		**383**	**182**	**0**	**565**
	%Total	67.8%	32.2%	0.0%	-
South East		-	-	-	-
	%Total	-	-	-	-

These data exclude - ❶ 146 skeletons from the Isle of Ensay data-set, as there were no data for numbers of adults and subadults.

6.8.3.2 Sex Distribution.

In contrast to the Early Medieval sites, the largest total adult sample sizes were found in the two northern regions, followed by the Eastern/Central Eastern and Central Southern regions (see Table 6.8:22 and Table 6.8:2). However, whilst the other regional samples all provided a high percentage of sexed adults (all over 90%), only 76.1% of the Far North adult sample was sexed. This was similar to the proportion of sexed adults from the Early Medieval Far North sample (see Table 6.8:2).

Table 6.8:22 Number and percentage of males, females and unsexed adults in the regions - Late Medieval period.

Regions: Late Medieval period		Sex				
		Male	Female	Unsexed	Total Sexed Adults	Total Adults
Far North		**224**	**173**	**125**	**397**	**522**
	%Total Adults	42.9%	33.1%	23.9%	76.1%	-
	%Sexed Adults	56.4%	43.6%	-	-	-
North/ North West		**356**	**154**	**35**	**510**	**545**
	%Total Adults	65.3%	28.3%	6.4%	93.6%	-
	%Sexed Adults	69.8%	30.2%	-	-	-
Eastern/ Central Eastern		**258**	**161**	**27**	**419**	**446**
	%Total Adults	57.8%	36.1%	6.1%	93.9%	-
	%Sexed Adults	61.6%	38.4%	-	-	-
Central Southern		**224**	**102**	**36**	**326**	**362**
	%Total Adults	61.9%	28.2%	9.9%	90.1%	-
	%Sexed Adults	68.7%	31.3%	-	-	-
South East		-	-	-	-	-
	%Total Adults	-	-	-	-	-
	%Sexed Adults	-	-	-	-	-

Table 6.8:23 Results of chi-square test comparing proportions of males and females against an expected equal distribution in the regions - Late Medieval period.

Regions: Late Medieval Period		M	F	Total Sexed Adults	X^2	d.f.	Significant	p
Far North	O	224	173	397	6.5516	1	**Yes**	p<0.025
	E	198.5	198.5					
North/ North West	O	356	154	510	80.0078	1	**Yes**	p<0.001
	E	255	255					
Eastern/ Central Eastern	O	258	161	419	22.4559	1	**Yes**	p<0.001
	E	209.5	209.5					
Central Southern	O	224	102	326	45.6564	1	**Yes**	p<0.001
	E	163	163					
South East	O	-	-	-	-	-	-	-
	E	-	-					

d.f. = degrees of freedom; **O** = Observed value; **E** = Expected value.

All regions had significantly more males than would be expected in a normal population (see Table 6.8:23), although the high proportion of males was only significant at the 2.5% level for the Far North sample. When the proportions of males and females for each regional sample were compared with each other, it can be seen that the Far North and Eastern/Central Eastern samples are both significantly different from the North/North West and Central Southern samples, but not from each other. Likewise the North/North West and Central Southern samples are significantly different from the other two samples, but not from each other (see Table 6.8:24). It appears that males comprise significantly more of the North/North West and Central Southern samples than the Far North and Eastern/Central Eastern samples. The former two regions both approach a distribution of 70% males to 30% females.

Table 6.8:24 Results of chi-square test comparing the proportions of males and females in pairs of regions - Late Medieval period.

Regions Compared: Late Medieval Period		X^2	d.f.	Significant	p
Far North	North/ North West	17.3362	1	**Yes**	p<0.001
Far North	Eastern/ Central Eastern	2.2380	1	No	p>0.05
Far North	Central Southern	11.4692	1	**Yes**	p<0.005
North/ North West	Eastern/ Central Eastern	6.9501	1	**Yes**	p<0.01
North/ North West	Central Southern	0.1117	1	No	p>0.05
Eastern/ Central Eastern	Central Southern	4.0884	1	**Yes**	p<0.05

d.f. = degrees of freedom.

6.8.3.3 Age Distribution.

6.8.3.3.1 Adults in General.

Again, as for the Early Medieval period, the two regions with the smallest proportion of Aged Adults were the North/North West (69.7%) and Far North (71.7%) regions (see Table 6.8:25 and Table 6.8:5). The Eastern/Central Eastern and Central Southern regions both had a larger proportion of Aged Adults at 84.3% and 82.2% respectively.

The only regions that did not show a significant difference in age distribution were the North/North West and Eastern/Central Eastern regions (see Table 6.8:26). In both regions, the YA categories had the lowest proportion of individuals, and just over half the individuals were in the oldest two age categories (see Table 6.8:25 and Figure 6.8:9). In contrast, the Far North region had a small percentage of individuals in both OA (15.1%) and YA (16.4%) categories, and was the only region to have more individuals in the youngest two age groups (55.1%) than the oldest two age groups (see Table 6.8:25 and Figure 6.8:9). The Central Southern region differed again in having the largest proportion of individuals in the OA group (39.7%), and consequently the highest percentage of individuals in the two oldest age categories (59.7%). The proportion of individuals in the YA group (21.3%) was also larger than that of the Far North and North/North West regions, but was similar to that in the Central Eastern region (22.6%).

Table 6.8:25 Number and percentage of adults in each age category in the regions - Late Medieval period.

Regions: Late Medieval Period	Aged Adults (% Total Aged)				Total Aged Adults	Unaged Adults	Total all Adults
	Young Adult	Young Middle Adult	Old Middle Adult	Old Adult			
Far North	188	444	341	173	1146	453	1599
	16.4%	38.7%	29.8%	15.1%	71.7%	28.3%	❶
	632		514				100%
	55.1%		44.9%				
North/ North-West	161	289	300	217	967	421	1388
	16.6%	29.9%	31.0%	22.4%	69.7%	30.3%	
	450		517				100%
	46.5%		53.5%				
Eastern/ Central Eastern	85	93	96	102	376	70	446
	22.6%	24.7%	25.5%	27.1%	84.3%	15.7%	
	178		198				100%
	47.3%		52.7%				
Central Southern	67	60	63	125	315	68	383
	21.3%	19.0%	20.0%	39.7%	82.2%	17.8%	
	127		188				100%
	40.3%		59.7%				
South East	-	-	-	-	-	-	-
	-		-	-			-
	-		-				-
	-		-				
Total	501	886	800	617	2804	1012	3816
	17.9%	31.6%	28.5%	22.0%	73.5%	26.5%	❶
	1387		1417				100%
	49.5%		50.5%				

These data exclude - ❶ 78 adults from Whithorn B and 84 of the 146 skeletons from the Isle of Ensay, for which there were no data on age.

Table 6.8:26 Results of Kolmogorov-Smirnov tests comparing adult age distributions between pairs of regions - Late Medieval period.

Regions Compared: Late Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
Far North / (North/ North West)	0.0861	Dmax 0.001	0.0852	Yes
Far North / (Eastern/Central Eastern)	0.1203	Dmax 0.001	0.1159	Yes
Far North / Central Southern	0.2459	Dmax 0.001	0.1241	Yes
(North/ North West)/ (Eastern/ Central Eastern)	0.0596	Dmax 0.05	0.0826	No
(North/ North West)/ Central Southern	0.1724	Dmax 0.001	0.1265	Yes
(Eastern/ Central Eastern)/ Central Southern	0.1255	Dmax 0.01	0.1245	Yes

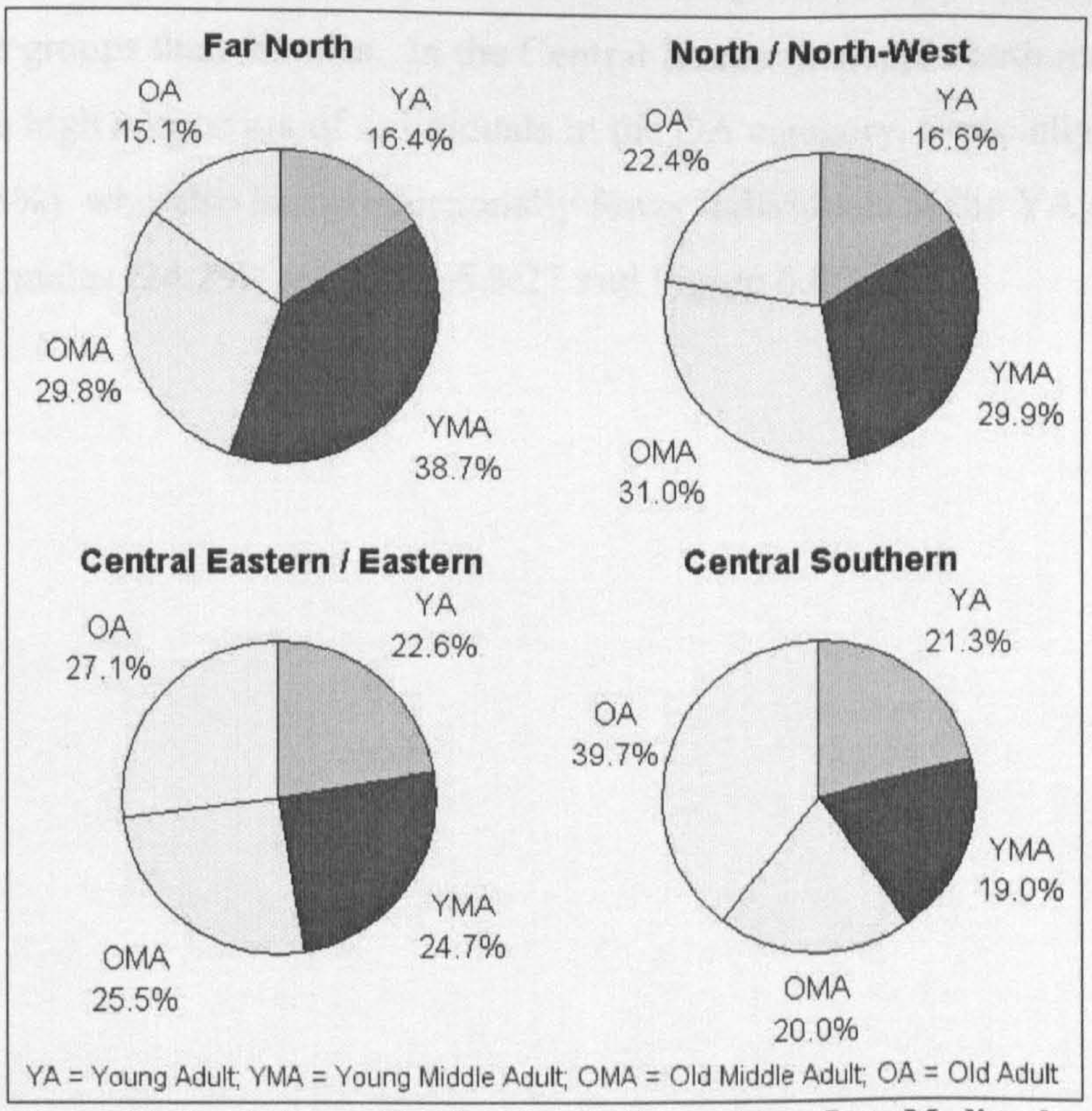

Figure 6.8:9 Adult age distributions in the regions - Late Medieval period.

6.8.3.3.2 Adults: Male and Female Subdivisions.

In all cases the proportion of aged individuals of both sexes was greater than 80%, with the exception of the Far North males, and in all regions the proportion of aged males and females was higher than that of the Aged Adults in general (compare Table 6.8:27 with Table 6.8:25).

In none of the regions were the age distributions of the males and females significantly different from each other (see Table 6.8:28). In the Far North sample proportionally more males were assigned to the OA category (29.3%), and the two older age groups in general (51.5%), than females (17.0% and 36.0% respectively), but both sexes had a small proportion of individuals in the YA group (see Table 6.8:27 and Figure 6.8:10). In the North/North West sample proportionally more females were classed as OA (25.0%), and fewer as YA (10.2%), than males (20.7% and 17.4% respectively), but overall both sexes had similar proportions in the two older, and younger, age groups. In the Eastern/Central Eastern region similar proportions of both sexes were found in each of the age categories, although the males had marginally more individuals in the two older age groups than females. In the Central Southern sample both males and females had a high proportion of individuals in the OA category, especially the females (46.5%), who also had proportionally fewer individuals in the YA category (17.2%) than males (24.2%; see Table 6.8:27 and Figure 6.8:10).

Table 6.8:27 Number and percentage of males and females in each age category in the regions - Late Medieval period.

Regions: Late Medieval Period		Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Far North	Male	15	33	22	29	99	32	131
		15.2%	33.3%	22.2%	29.3%	75.6%	24.4%	❶
		48		51				100%
		48.5%		51.5%				
	Female	18	46	19	17	100	21	121
		18.0%	46.0%	19.0%	17.0%	82.6%	17.4%	❷
		64		36				100%
		64.0%		36.0%				
North/ North West	Male	53	85	103	63	304	52	356
		17.4%	28.0%	33.9%	20.7%	85.4%	14.6%	
		138		166				100%
		45.4%		54.6%				
	Female	13	40	43	32	128	26	154
		10.2%	31.3%	33.6%	25.0%	83.1%	16.9%	
		53		75				100%
		41.4%		58.6%				
Eastern/ Central Eastern	Male	51	53	63	60	227	31	258
		22.5%	23.3%	27.8%	26.4%	88.0%	12.0%	
		104		123				100%
		45.8%		54.2%				
	Female	31	37	31	41	140	21	161
		22.1%	26.4%	22.1%	29.3%	87.0%	13.0%	
		68		72				100%
		48.6%		51.4%				
Central Southern	Male	48	40	36	74	198	26	224
		24.2%	20.2%	18.2%	37.4%	88.4%	11.6%	
		88		110				100%
		44.4%		55.6%				
	Female	17	18	18	46	99	3	102
		17.2%	18.2%	18.2%	46.5%	97.1%	2.9%	
		35		64				100%
		35.4%		64.6%				
South East	Male	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
	Female	-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-		-				-
		-		-				
	Table continues on next page							

Table 6.8:27 (Continued).

Late Medieval Regions		Aged Adults (% Total Aged) Young Adult	Young Middle Adult	Old Middle Adult	Old Adult	Total Aged Adults	Unaged Adults	Total all Adults
Totals	Male	167	211	224	226	828	141	969
		20.2%	25.5%	27.1%	27.3%	85.4%	14.6%	❶
		378		450				100%
		45.7%		54.3%				
	Female	79	141	111	136	467	71	538
		16.9%	30.2%	23.8%	29.1%	86.8%	13.2%	❷
		220		247				100%
		47.1%		52.9%				

These data exclude - ❶ 93 males from Blackfriars, Carlisle, and ❷ 52 females from Blackfriars, Carlisle, as details of age distribution were not provided.

In all regions over half of the males were placed in the two older age groups. When the male age distributions were compared between regions the only significant difference was found between the North/North West and Central Southern regions (see Table 6.8:29). The Central Southern sample had proportionally far more males in the OA category (37.4%) than did the North/North West sample (20.7%), which also had proportionally fewer males in the YA group (17.4%; see Table 6.8:27 and Figure 6.8:10).

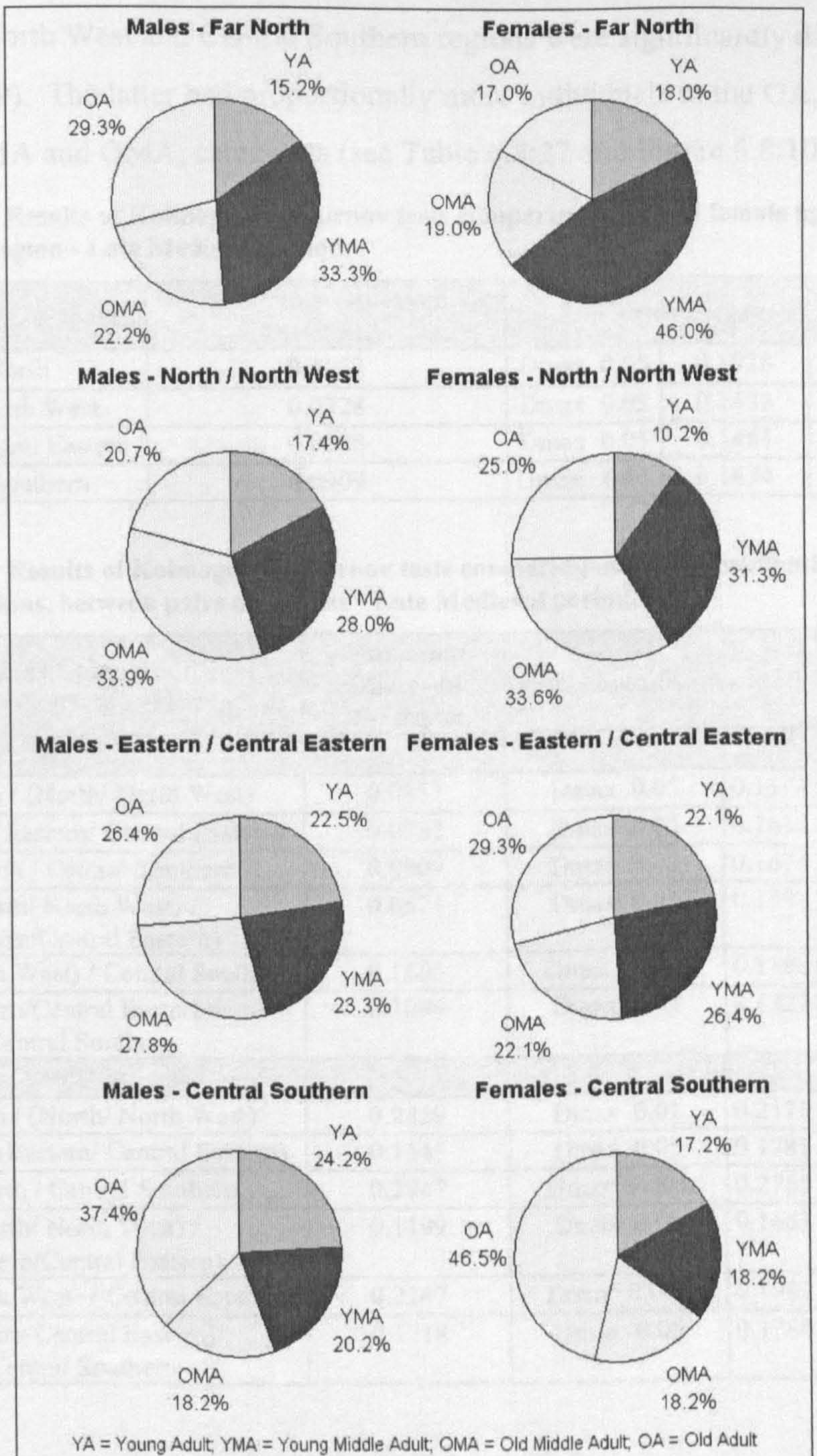

Figure 6.8:10 Male and female age distributions in the regions - Late Medieval period.

In three of the regions over half the females were placed in the two older age groups, the exception being the Far North. The age distribution of the females in this region was significantly different from that of the North/North West and Central Southern samples (see Table 6.8:29). Both the latter had a lower percentage of females in the YMA age group, a higher percentage in the OA group (especially the Central Southern sample), and the North/North West region also had proportionally fewer individuals in the YA category. As with the male age distributions, the female age distributions of the North/North West and Central Southern regions were significantly different (see Table 6.8:29). The latter had proportionally more individuals in the OA, and fewer in the YA, YMA and OMA, categories (see Table 6.8:27 and Figure 6.8:10).

Table 6.8:28 Results of Kolmogorov-Smirnov tests comparing male and female age distributions within each region - Late Medieval period.

Male/Female Compared	Maximum Observed Difference	Dmax Significance level		Significant ?
Far North	0.1552	Dmax 0.05	0.1928	No
North/ North West	0.0728	Dmax 0.05	0.1433	No
Eastern/ Central Eastern	0.0285	Dmax 0.05	0.1461	No
Central Southern	0.0909	Dmax 0.05	0.1674	No

Table 6.8:29 Results of Kolmogorov-Smirnov tests comparing male age distributions, and female age distributions, between pairs of regions - Late Medieval period.

Regions Compared: Late Medieval Period	Maximum Observed Difference	Dmax Significance level		Significant ?
Males:				
Far North / (North/ North West)	0.0857	Dmax 0.05	0.1574	No
Far North / (Eastern/ Central Eastern)	0.0732	Dmax 0.05	0.1638	No
Far North / Central Southern	0.0909	Dmax 0.05	0.1674	No
(North/ North West) / (Eastern/Central Eastern)	0.0571	Dmax 0.05	0.1193	No
(North/North West) / Central Southern	0.1665	Dmax 0.005	0.1580	**Yes**
(Eastern/Central Eastern)/ Central Southern	0.1094	Dmax 0.05	0.1322	No
Females:				
Far North / (North/ North West)	0.2259	Dmax 0.01	0.2175	**Yes**
Far North / (Eastern/ Central Eastern)	0.1543	Dmax 0.05	0.1781	No
Far North / Central Southern	0.2947	Dmax 0.001	0.2765	**Yes**
(North/ North West) / (Eastern/Central Eastern)	0.1199	Dmax 0.05	0.1663	No
(North/North West) / Central Southern	0.2147	Dmax 0.025	0.1981	**Yes**
(Eastern/Central Eastern)/ Central Southern	0.1718	Dmax 0.05	0.1786	No

6.8.3.4 Caries Prevalence.

6.8.3.4.1 Teeth from Adults.

Again, the Central Southern region had the highest caries prevalence in teeth from adults (14.1%; see Table 6.8:30 and Figure 6.8:11) and this was significantly different from all other regions (see Table 6.8:31). The Eastern/Central Eastern sample also had a relatively high caries prevalence rate at 10.4%, and this was also significantly different from all other regions (see Table 6.8:31). The two northern regions had lower prevalence rates, with the North/North West sample having the lowest (6.8%).

There was no significant difference between these two regions (see Table 6.8:31).

Table 6.8:30 Caries prevalence in the regions - Late Medieval period.

Regions: Late Medieval Period	Teeth from								
	Adults			Males			Females		
	C	P	%	C	P	%	C	P	%
Far North	1,140	16,107	7.1%	77	2,277	3.4%	127	2,153	5.9%
North/ North West	1,036	15,301	6.8%	454	4,992	9.1%	191	1,828	10.4%
Eastern/ Central Eastern	671	6,452	10.4%	378	3,599	10.5%	274	2,086	13.1%
Central Southern	730	5,183	14.1%	448	3,294	13.6%	269	1,442	18.7%
South East	-	-	-	-	-	-	-	-	-

C = With Caries; **P** = Number of teeth present.
See **Appendix 17** for source data for each category.

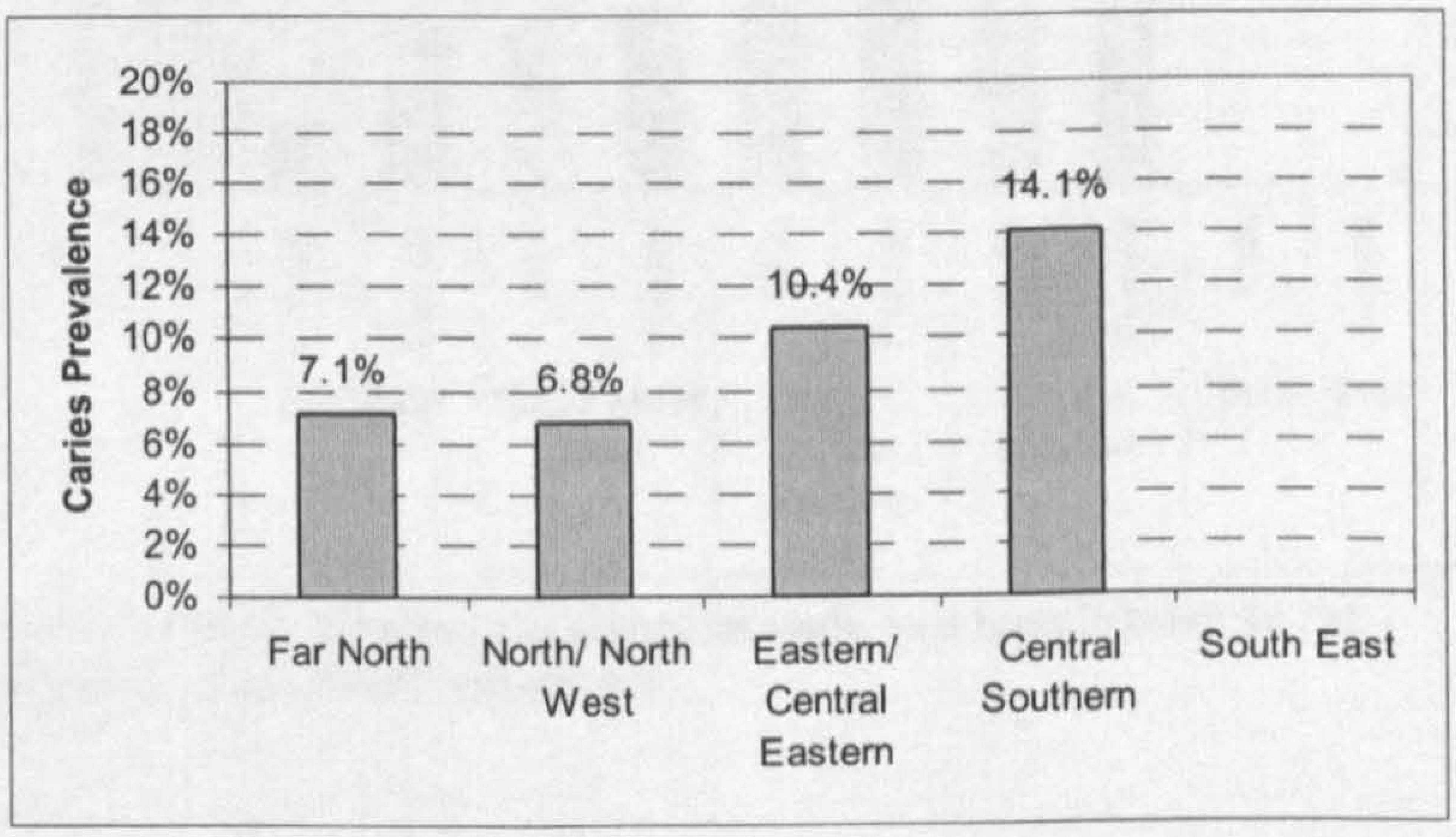

Figure 6.8:11 Caries prevalence in adult teeth in the regions - Late Medieval period.

Table 6.8:31 Results of chi-square test comparing caries prevalence (adult teeth) in pairs of regions - Late Medieval period.

Orders Compared: Late Medieval Period		X²	d.f.	Significant	p
Far North	North/ North West	1.1459	1	N	p>0.05
Far North	Eastern/ Central Eastern	68.8633	1	Yes	p<0.001
Far North	Central Southern	240.2841	1	Yes	p<0.001
North/ North West	Eastern/ Central Eastern	82.6541	1	Yes	p<0.001
North/ North West	Central Southern	262.8699	1	Yes	p<0.001
Eastern/ Central Eastern	Central Southern	36.8423	1	Yes	p<0.001

d.f. = degrees of freedom.

6.8.3.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence rates for male and female teeth are shown in Table 6.8:30 and Figure 6.8:12). In all four regions female teeth exhibited a higher caries prevalence rate than the male teeth, and this difference was significant for all but the North/North West region (see Table 6.8:32).

As with the adult teeth the highest caries prevalence rate was observed in the Central Southern region for both male and female teeth, followed by the Eastern/Central Eastern region. Whereas the caries prevalence in adult teeth had been similar between the Far North and North/North West regions, the caries prevalence in both male and female teeth in the Far North sample was half of that in the North/North West sample. The difference in caries prevalence was significant between all regions for teeth from both sexes (see Table 6.8:33).

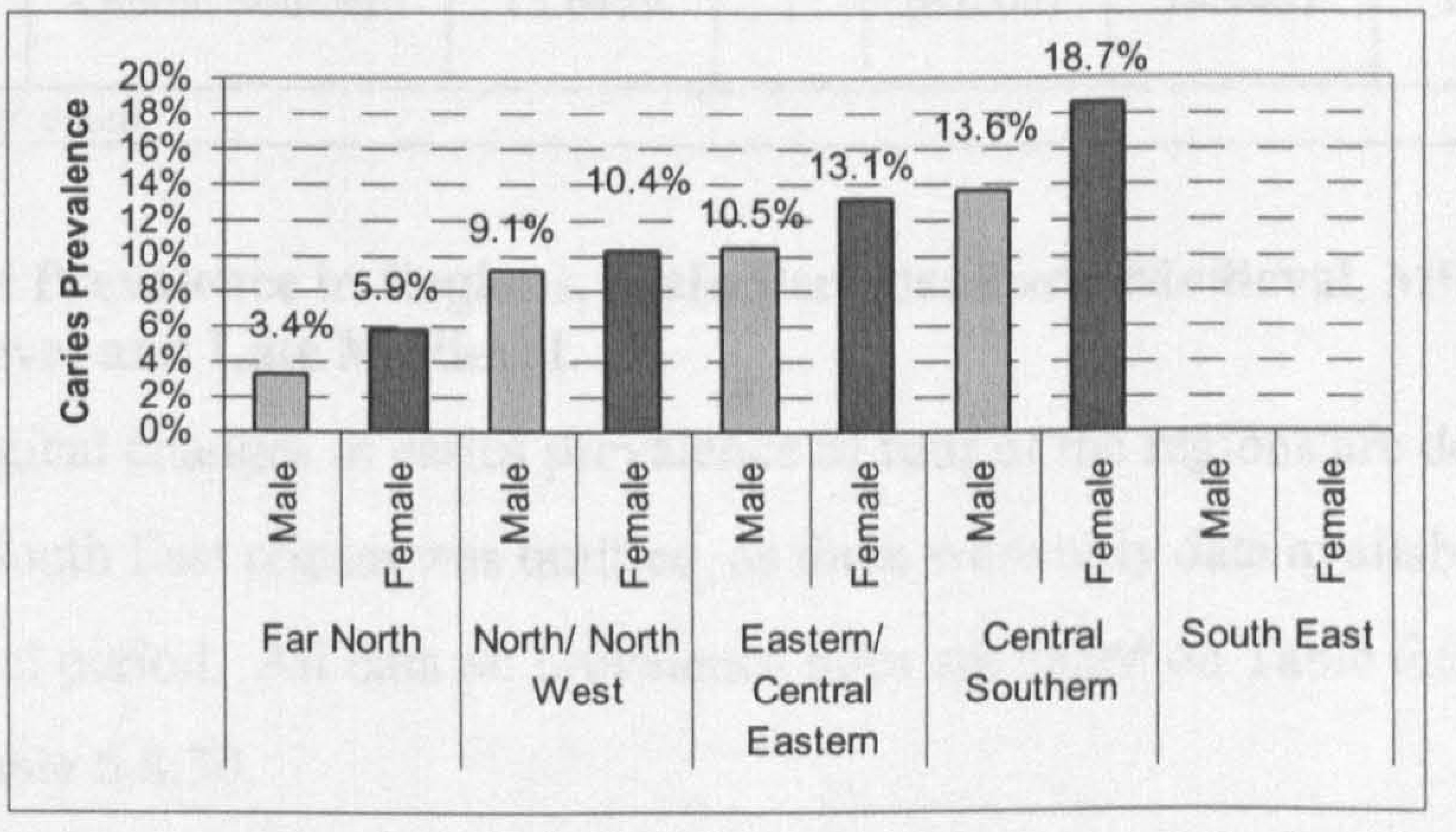

Figure 6.8:12 Caries prevalence in male and female teeth in the regions - Late Medieval period.

Table 6.8:32 Results of chi-square test comparing caries prevalence between male and female teeth within each region - Late Medieval period.

Region: Late Medieval	X²	d.f.	Significant	p
Far North	15.9608	1	**Yes**	p<0.001
North/ North West	2.8648	1	No	p>0.05
Eastern/ Central Eastern	9.0118	1	**Yes**	p<0.005
Central Southern	19.9417	1	**Yes**	p<0.001
d.f. = degrees of freedom.				

Table 6.8:33 Comparison of caries prevalence in male and female teeth between regions - Late Medieval period: chi-square values and significance level.

Regions Compared: Late Medieval Period		Male Teeth			Female Teeth		
		X^2	d.f.	p	X^2	d.f.	p
Far North	North/ North West	75.3705	1	p<0.001	27.8445	1	p<0.001
Far North	Eastern/ Central Eastern	99.0067	1	p<0.001	64.7772	1	p<0.001
Far North	Central Southern	164.7088	1	p<0.001	143.3578	1	p<0.001
North/ North West	Eastern/ Central Eastern	4.7424	1	p<0.05	6.7170	1	p<0.01
North/ North West	Central Southern	41.5350	1	p<0.001	44.9051	1	p<0.001
Eastern/ Central Eastern	Central Southern	15.6459	1	p<0.001	19.9461	1	p<0.001

d.f. = degrees of freedom.

6.8.4 Caries Prevalence in Regions, Main Periods: Early Medieval, Middle Medieval and Late Medieval.

The chronological changes in caries prevalence of four of the regions are described below. The South East region was omitted, as there were only data available for the Early Medieval period. All data on prevalence rates are based on Table 6.8:10, Table 6.8:20 and Table 6.8:30.

6.8.4.1 Far North.

There were no data on caries prevalence for the Middle Medieval period in this region. The caries prevalence in the Late Medieval adult teeth (7.1%) was double that of the Early Medieval period (3.5%; see Figure 6.8:13), and this difference was statistically significant ($X^2 = 61.8064$, $p<0.001$, d.f. = 1).

6.8.4.2 North/North West.

The caries prevalence rate in the Late Medieval period (6.8%) was only marginally higher than that in the Early Medieval period (6.2%; see Figure 6.8:14), and this difference was not significant ($X^2 = 1.1270$, $p>0.05$, d.f. = 1). The prevalence rate in the Middle Medieval period was lower than both, at 4.3%, and was significantly different from both the Early ($X^2 = 6.8530$, $p<0.01$, d.f. = 1) and Late ($X^2 = 13.1648$, $p<0.001$, d.f. = 1) Medieval samples for this region.

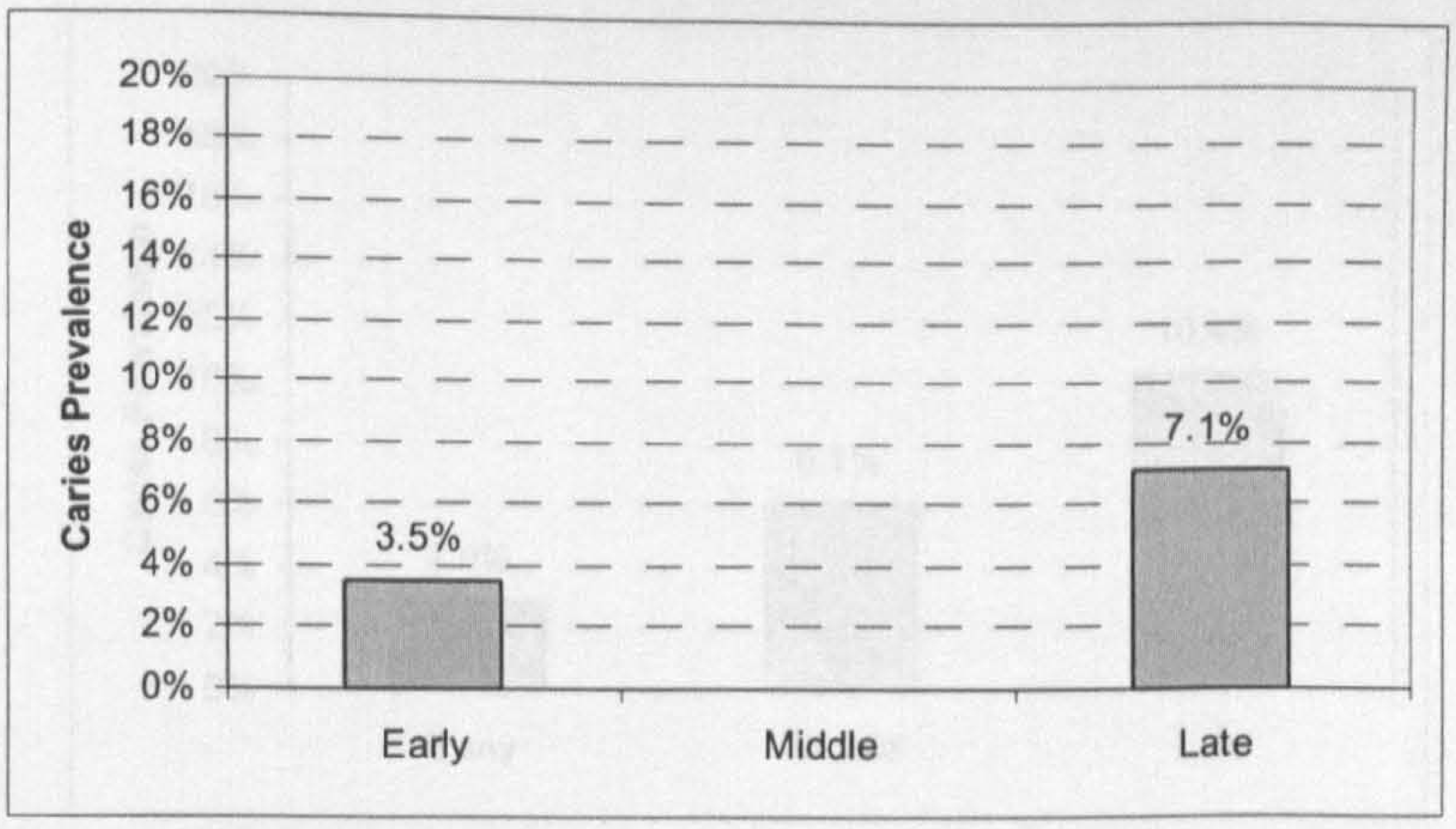

Figure 6.8:13 Caries prevalence in adult teeth in the Far North region - Early, Middle and Late Medieval periods.

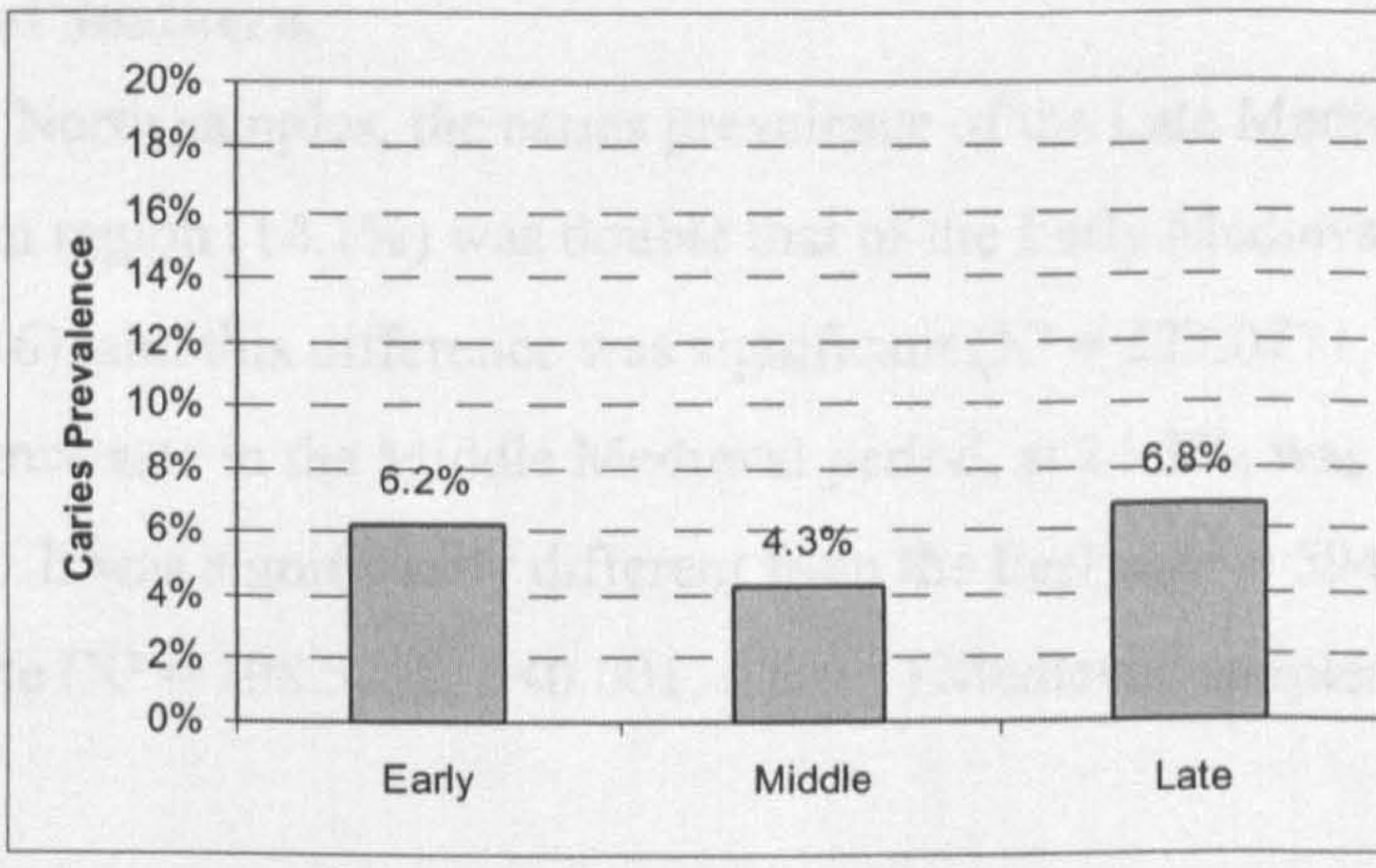

Figure 6.8:14 Caries prevalence in adult teeth in the North/ North West region for- Early, Middle and Late Medieval periods.

6.8.4.3 Eastern/Central Eastern.

The caries prevalence rate in the Late Medieval period (10.4%) was over triple that of the Early Medieval sample (2.9%; see Figure 6.8:15), with the difference significant at the 0.1% level ($X^2 = 274.5925$, $p<0.001$, d.f. = 1). The prevalence rate in the Middle Medieval period lay between both, at 6.1%, and was significantly different from both the Early ($X^2 = 76.4747$, $p<0.001$, d.f. = 1) and Late ($X^2 = 89.1648$, $p<0.001$, d.f. = 1) Medieval samples.

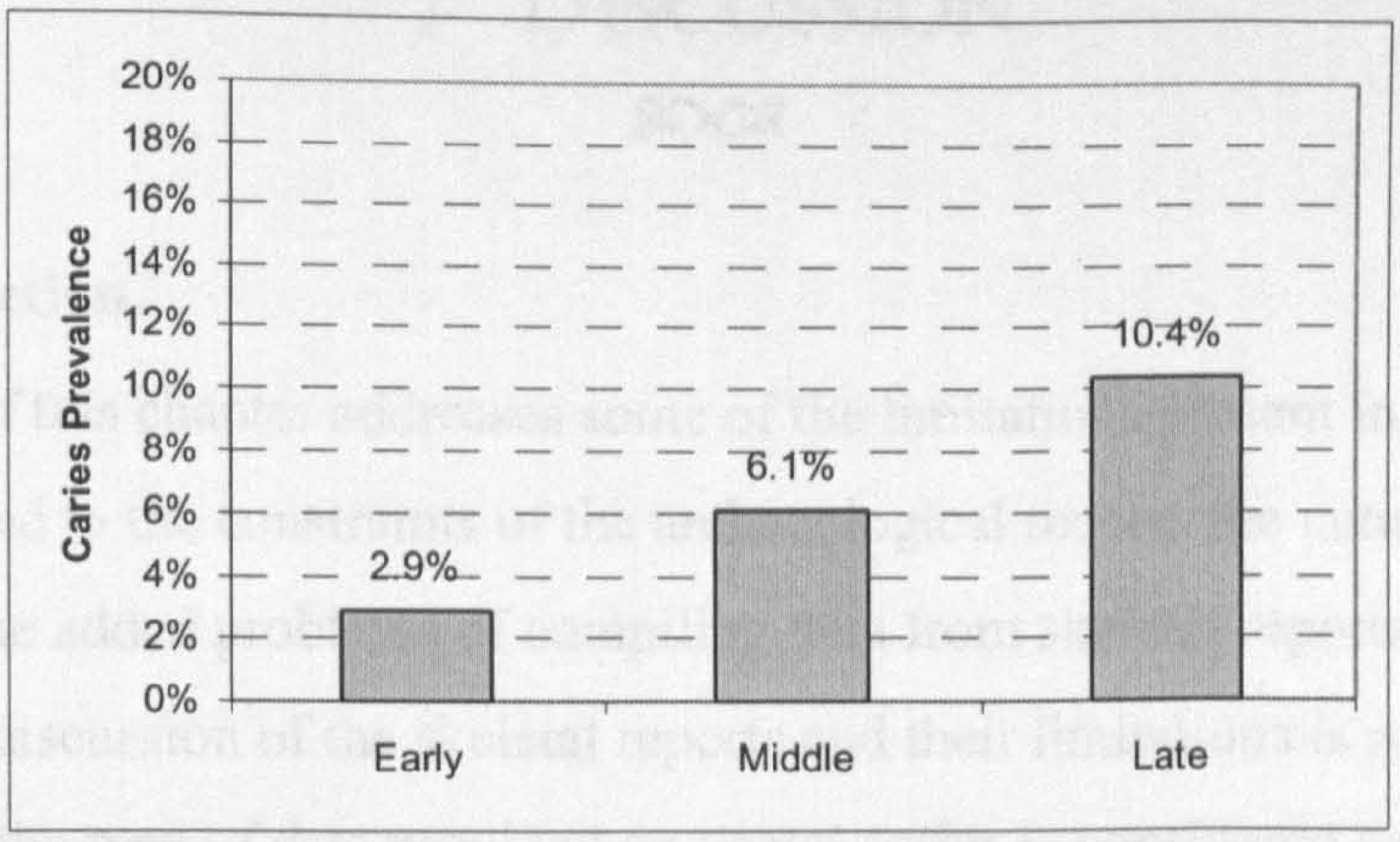

Figure 6.8:15 Caries prevalence in adult teeth in the Eastern/ Central Eastern region - Early, Middle and Late Medieval periods.

6.8.4.4 Central Southern.

As with the Far North samples, the caries prevalence of the Late Medieval sites in the Central Southern region (14.1%) was double that of the Early Medieval sample (6.5%; see Figure 6.8:16), and this difference was significant ($X^2 = 223.0771$, $p<0.001$, d.f. = 1). The prevalence rate in the Middle Medieval period, at 24.3%, was considerably more than both. It was significantly different from the Early ($X^2 = 594.1502$, $p<0.001$, d.f. = 1) and Late ($X^2 = 108.5752$, $p<0.001$, d.f. = 1) Medieval samples.

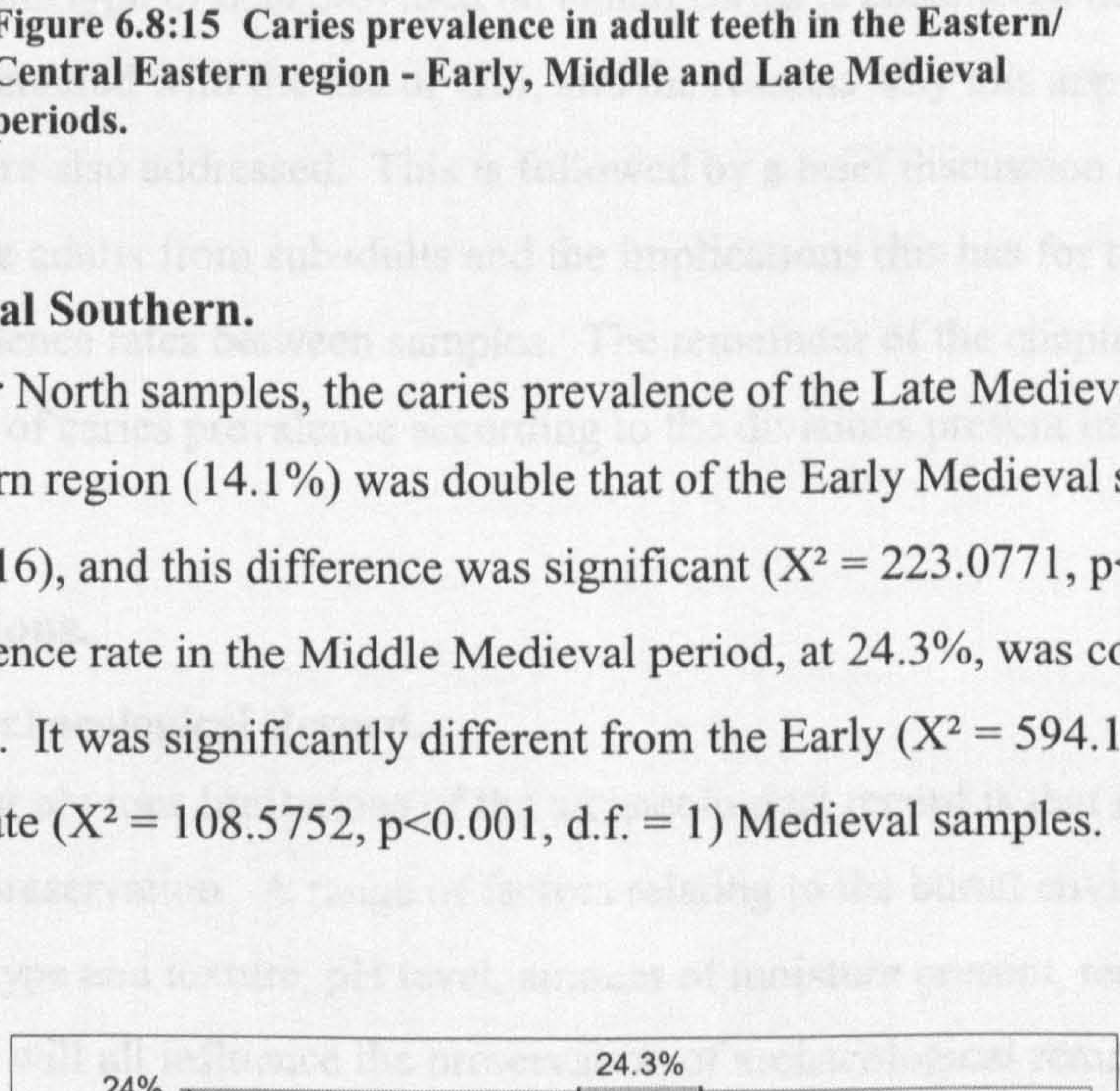

Figure 6.8:16 Caries prevalence in adult teeth in the Central Southern region for - Early, Middle and Late Medieval periods.

7 Discussion

7.1 Introduction.

The first part of this chapter addresses some of the limitations present in the data. These are related to the constraints of the archaeological record, the nature of skeletal samples, and the added problems of compiling data from skeletal reports prepared by others. A full discussion of the skeletal reports and their limitations is provided in Chapter 8, but the type of data provided on dental caries is considered here. The problems encountered with the use of GIS, and the reasons why this approach was unsuccessful, are also addressed. This is followed by a brief discussion of the age used to separate adults from subadults and the implications this has for the comparison of caries prevalence rates between samples. The remainder of the chapter is devoted to a discussion of caries prevalence according to the divisions present in Chapter 6.

7.2 Limitations.

7.2.1 The Archaeological Record.

One of the most obvious limitations of the archaeological record is that it is largely dependant on preservation. A range of factors relating to the burial environment including soil type and texture, pH level, amount of moisture present, temperature, and animal activity will all influence the preservation of archaeological remains. The degree of consistency within the burial environment is also important, as fluctuations in these conditions can be more detrimental than a stable environment (Cronyn, 1990; Janaway, 1996; Garland, 1987). Different materials will react differently to the same burial environment, so conditions favourable to the preservation of one type of material will be detrimental to the survival of another (Cronyn, 1990). Preservation of skeletal material will vary according to these factors, and the condition of the bones and teeth present will have an impact on the quantity and quality of data that can be retrieved from their study (Waldron, 1987b). In addition, some activities produce more tangible evidence than others and so some practices are more visible than others in the archaeological record; for example, burial within a defined cemetery is more archaeologically visible than excarnation.

Another point to make is that archaeological data are only available for the places where surveys and excavations have been carried out, so places where no data have been gathered do not mean than a certain type of site was absent. This biased sample is a reflection of archaeological activity, which is usually more intense in areas of modern development, such as towns and new roads. For example, Massegrande (1995) discovered that the distribution of sites in an area of the Mediterranean basin reflected 'territories' surveyed by different groups, and the majority of sites were located within 5 km of a major modern feature, such as a road or town. Similar biases may be in operation in Britain, where areas favoured by individuals with certain research interests or those near a large and active archaeological unit may receive more attention, and the same association with modern development occurs. In the south east of England many Early Medieval cemeteries were discovered during the course of gravel extraction, and so the known cemeteries probably do not reflect the original distribution (Williamson, 1988). These biases of preservation and excavation patterns are visible in the distribution of sites used for this research. The maps of Early Medieval, Middle Medieval and Late Medieval site distribution (see Figures 5.2:3, 5.2:4 and 5.2:5) illustrate the concentration of sites in the south and east of England, especially in the Early Medieval period, whilst the Late Medieval sites are generally found in urban areas.

When examining the caries prevalence in different regions this assumes that the individuals buried in the cemeteries of that region lived in that area, which is not necessarily the case. For the Late Medieval period there are records of the transport of bodies over some distance, especially those of the aristocracy, to the desired burial location (Daniell, 1997). Daniell also records instances where strangers were buried in the parish churchyard, which might indicate people who were not local residents. For the Early Medieval period, studies of stable isotopes have shown that some of the individuals at West Heslerton originated from a different area to others (Budd, *et al.*, 2004), but when they migrated and how long they had been living in the area before death are unknown.

Data on the economy and diet of past populations can be reconstructed from the study of plant and animal remains at archaeological sites (Dark, 2000). However, problems of preservation and retrieval during excavation emerge again, as some types of environmental data tend to be better preserved than others and excavation practices may bias against the retrieval of certain types of evidence. For example, fish bones are often small and underrepresented if sieving is not carried out; even different types of sieving will affect the retrieval of small bones (O'Connor, 1991). For sites excavated during the 1970s and earlier, sieving was rarely carried out and valuable data have been lost from these assemblages (Huntley and Stallibrass, 1995). In addition, such assemblages relating to economy are usually associated with settlements but, in comparison to the number of cemetery sites, few settlements have been located and excavated for the Early Medieval period (Hills, 1999). Data from research into stable isotope ratios can be incredibly useful in reconstructing past diet (Ambrose, *et al.*, 1997; Larsen, *et al.*, 1992; Pate, 1994), but few such studies have been conducted in Britain (Mays, Simon A., 1997; Privat and O'Connell, 2002). These restrictions limit the integration of cultural data with the biological data obtained through studying the skeletal remains.

7.2.2 Skeletal Samples.

Many of the limitations inherent to skeletal samples have already been discussed in detail in Section 2.2. Essentially, the skeletal sample available for study may not be an accurate representation of the original population. Exclusion of some individuals from the cemetery, selection of individuals for burial in certain locations, differential preservation of those buried, incomplete excavation, and the potential for damage to skeletons during and after excavation, all affect the composition of the skeletal sample seen by the osteologist (Waldron, 1994a, 1987b; Caffell, *et al.*, 2001). These factors will have influenced the samples from each of the sites included in this study, but not all will be influenced in the same way. In addition, the skeletons excavated from a cemetery are often treated as a cross-section of the population, but most cemeteries were in use for decades if not centuries, and the individuals will not all have been alive at the same time. Different generations may have experienced different environments and changes in cultural practice. Since in most cases accurate dates for individuals cannot be obtained, the skeletal samples have to be treated as a homogenous group, and this will have influenced the results. Furthermore, data from different sites were combined in order to examine large-scale trends, but this will have obscured differences between individual sites that may have been of importance.

7.2.3 The Data Source.

This research had to rely on data collected by others, as it would have been totally impractical for the author to collect data from sufficient skeletal collections to meet the aims of the study. However, this approach has many limitations. Since the skeletal collections were all examined, and the reports written, by different individuals with varying degrees of training and experience, across the course of several decades, the potential for inter-observer error is high. There is no guarantee that all osteologists have employed the same diagnostic criteria when recording dental caries, and it seems highly likely that variations in what is accepted as a carious lesion have occurred between individuals. This issue of inter-observer error means caries prevalence may have been both over- and under-diagnosed in the sites used for this study.

Inter-observer error may also have affected the data on sex distribution. However, sex estimation has been shown to be around 90-95% accurate if the pelvis and skull are available, although some errors do occur (Meindl, *et al.*, 1985a), and it also has the advantage of two biologically defined categories into which all researchers are attempting to divide the skeletons. Extra categories, such as possible males and females, or unsexed individuals, are created, but at least the categories are broadly comparable even if there may be some debate about which skeletons get put into them.

There are considerably more problems when attempting to examine the age distribution of the samples than there are when considering the sex distribution, as age estimation is much more fraught with the potential for error. Since adults are no longer growing and developing at a genetically programmed rate, degenerative changes to the skeleton must be used to estimate age instead (Ubelaker, 1989; Schwartz, 1995). However, rates of ageing vary between individuals, and fluctuate according to environmental and occupational pressures, so the age-at-death estimate obtained reflects the biological age of the individual rather than the true chronological age. Many of the methods used to estimate age have been developed using recent populations, but it is possible that rates of aging have changed through time (Molleson, 1995). Many studies have demonstrated that the methods currently available have a tendency to underage the older individuals and overage the younger individuals (for example, Molleson, 1995; Murray and Murray, 1991; Key, *et al.*, 1994), and several of the methods, such as the technique developed for age estimation using the auricular surface, have a high inter- and intra-observer error and have been found to be difficult to apply (Buckberry and Chamberlain, 2002). In addition, most have only recently been developed or improved upon, and so were not available when a large proportion of the skeletal collections used in this study were originally recorded.

These factors do not inspire confidence when the data gathered by several individuals over the course of a few decades are compiled and compared with each other. To compound the problem, the definition of age categories is largely arbitrary and the choice of the osteologist, and the wide variety in age categories used has been an extra hindrance during the course of this research. The approach to assigning skeletons to different age categories could also vary with the individual; for example, in one instance the following statement was encountered:

> "It should be noted that many of the individuals in the categories 'Y-MA' and 'MA-Old' were put there simply because it was impossible to decide which single category they fitted into" (Anderson and Birkett, 1991: p2).

This decision has artificially inflated the number of individuals in the two middle-aged categories in this sample when another more appropriate choice might have been to place these individuals into a separate category for Unaged Adults. These inconsistent data gathered from all the reports had to be standardised in order to provide some idea of the age structure of the populations under study, but in doing so another layer of error has probably been introduced. It must be stressed that the data can only allow a general impression of the number of individuals in each age category, and the figures must not be taken too literally.

Another major limitation is the inability to associate the data on age-at-death directly with dental caries. In only a few skeletal reports were data on caries prevalence in teeth given for different age categories, meaning that data on the age distribution of the whole population had to be used instead. Not all the individuals in the sample necessarily had teeth, and any biases towards a particular age group containing more individuals with surviving dentitions will mean that the age distribution of the whole sample will not reflect that of those individuals contributing data on caries prevalence. In addition, it is not possible to compare caries prevalence in different age groups between samples and so obtain more solid data on the presence or absence of trends in caries prevalence.

A further limitation of this study is that data on postmortem and ante-mortem tooth loss (AMTL) were not collected. Postmortem tooth loss may influence caries prevalence through the loss of more anterior than posterior teeth (Hillson, 1996, 2001). Different patterns of postmortem tooth loss, resulting from variations in preservation, excavation methods and post-excavation processing, may have occurred in the different sites incorporated in this study. However, postmortem tooth loss was not reported in all skeletal reports, and to be really useful it would need to be reported by each tooth type rather than be given as one overall figure, which was the more common practice. Ante-mortem tooth loss is often associated with caries, although other factors may have been more important in past populations than they are now, such as pulp exposure due to heavy attrition, or periodontal disease (Hillson, 2001; Brothwell, 1963). Again data on AMTL were not given in all reports and, as for postmortem tooth loss, few gave data on AMTL prevalence per tooth type. It is possible that in some cases a high rate of ante-mortem tooth loss will have obscured high caries prevalence, as the carious teeth lost ante-mortem will not be included in the tooth count and a low caries prevalence result.

Interpretation of the results would have been facilitated by more detailed data on the location of carious lesions, both tooth type and position on the tooth, but such data was rarely provided and so comparison had to be made at the most basic level. Data on other pathological conditions, both dental and skeletal, would also have assisted interpretation of the results. Examining a combination of dental diseases may be more informative as to the nature of the dietary changes occurring (Freeth, 1999), and the evidence provided by stature (which reflects environmental stress to some degree) and skeletal changes associated with episodes of undernutrition and stress might also be helpful in evaluating the data on caries. However, although stature was reported fairly consistently, the data for pathological conditions tended to be poor and incomparable between sites. Further issues relating to the collation of data from reports prepared by different individuals are discussed in more detail in Section 7.3 and Chapter 8.

7.2.4 Geographical Information Systems (GIS).

The original intention of this research was to apply the use of GIS to the study of disease in past populations. However, the poor quality of data available in the skeletal reports meant that comparable data for each site were difficult to obtain. Another issue was the difficulty in finding data on geographical variables that could be used with the GIS program. Although data on the environment in the past exist, these reconstructions relate to specific sites or small areas, and have not been carried out for the country as a whole. In addition, the data were not held in a format that could be easily incorporated into a GIS program. Data on modern environmental and geographical variables also exist, but could be hard to find in a form compatible with GIS. Even if data were found they often did not apply to the areas required, or did not give the required information. Furthermore, such data is usually expensive and trying to ascertain whether the data on offer will be useful is made more difficult by not being able to see it beforehand. It is also likely that modern data will not reflect the conditions of the past, as climatic conditions have changed, rivers have altered course, sea levels have risen or fallen, and modern human activity has affected the levels of chemicals and trace elements present in soils and water (Verhagen, *et al.*, 1995).

Although GIS has the potential to be extremely useful with respect to some research questions, such as the association between fluoride levels in the water, or other trace elements in the soil, and dental caries, the main problem remains with obtaining the data required. An additional problem is the location of archaeological sites. For example, if an area of high fluoride has been identified, but there are no skeletons from archaeological sites in the region, then nothing can be done to address this problem (except the rather impractical option of searching for and excavating a site in the hope that it will yield enough skeletons for study which, aside from being expensive, will probably not succeed).

7.3 Evidence of Dental Caries in Skeletal Reports.

7.3.1 Skeletal Reports Lacking Caries Data.

Dental caries is one of the more common diseases that can be diagnosed in skeletal material, and it would be reasonable to assume that most collections of human remains, especially those dated to more recent times, will display some evidence of it (Aufderheide and Rodríguez-Martín, 1998). Therefore, it would be understandable to expect all skeletal reports to include data on dental caries (Hillson, 2001). Even if evidence of caries is absent it is not unreasonable to trust that this fact will be reported. However, as this study discovered, not all skeletal reports provided data on dental caries; in actuality, of those data-sets originally recorded, the proportion that provided some useable data on dental caries was around 85%. By this, it is meant that either the number of individuals with dentitions and the number of individuals with caries had been recorded, and/or the number of teeth present and number of teeth with caries had been recorded. Where this was the case, the caries prevalence rate could be determined for either individuals or teeth, or both, and the data from more than one data-set could be combined if required. In the following discussion the references pertaining to each data-set can be found in Appendix I.

The reasons why 15% of the data-sets joined the list of those that did not provide caries data could be divided into four categories:

a) Caries data mislaid – (1 data-set).
b) Caries not mentioned in the report at all – (3 data-sets).
c) Caries data vague, and generalised comments made in the text – (3 data-sets).
d) Caries data incomplete – (7 data-sets).

The first case, where the data had been mislaid, was that of the Royal Mint site in London, which is currently being prepared for publication (Bill White, MoLSS, *pers. comm.*). In this case the dentitions and the rest of the skeletal remains were examined separately by different individuals. This practice of separate examination of teeth and bones had also occurred for other samples: examples include Whithorn and the Franciscan Church, Hartlepool, where both skeletal and dental reports were published together in the same volume, and Aberdeen Carmelite Friary, where the two reports were published in completely different places; the skeletal report as part of the site report and the dental report as a paper in a British Archaeological Report. Unfortunately the Royal Mint dental report could not be found, and only the unpublished skeletal report was available when the author visited the Museum of London Specialist Services archives in order to collect data for this research.

In three cases no mention at all was made of dental caries in the skeletal report. One of these sites (Holborough) was published in the 1950s in response to a very different set of research interests, demonstrated by the focus on cranial morphology and the lack of data on any form of postcranial pathology, and before current levels of knowledge and methods of analysis had developed. Of the remaining two skeletal reports, one

(Milton Keynes Village) was prepared in 1993 and remains unpublished. The excavation of this site was described as 'salvage' and apparently the skeletal remains were fragmented and disarticulated. The report concentrates on providing data on the demographic profile of the skeletal remains but gives no detail on pathology, and the catalogue provides only general information. The other site (Ailcy Hill) was published in 1996 (although it is unclear as to the exact date the report was written), and despite data on numerous other pathological conditions being provided and discussed, dental caries is omitted from the published report.

Three of the skeletal reports made a generalised and subjective comment on the occurrence of dental caries in that skeletal collection, without providing any hard data. The dates of publication span a considerable period, with one site published in the early 1920s (Bidford-on-Avon), another written in the mid 1970s remains unpublished (Chelmsford Dominican Priory), and the last one was published in the mid 1990s (St Giles' Hospital). The types of comment made include: "a few instances of dental caries"; "most of the jaws showed some caries cavities in the teeth"; and "low levels of dental caries". Such vague comments were encountered in several other reports, but either the data was present in a table, or it was possible to collect the data from the skeletal catalogue, which was not the case here. Without numbers it is impossible to compare skeletal remains from one site with another in any constructive way. How does one define "a few", or "most", or "low levels"? Others have also noted this problem, but without necessarily addressing the issue satisfactorily themselves. For example, Kerr (1986: p189) complained (in relation to dental caries) that there had been "much subjective reporting in the past which proved to be of very little value if worthwhile comparisons were to be made", but then goes on to provide a descriptive and subjective report on the teeth from the Aberdeen Carmelite Friary that contains little in the way of facts and figures! Ortner (1991; 1994), in particular, has campaigned for better quality recording and reporting of palaeopathological data in order to address the issue of lack of comparability between reports. These issues will be discussed in more detail in Chapter 8.

The final cause of lack of data on dental caries encompassed those reports where some data had been provided, but not enough that it could be used in any meaningful way. This included giving the number of individuals and teeth with caries, but not the number of individuals and teeth present. A variation of this was providing the number of individuals with dentitions and the number of teeth with caries, but not the number of individuals with caries or teeth present (or *vice versa*). In these cases (Dinton; Great Chesterford; Nazeingbury; South Acre) a prevalence rate can be calculated for neither teeth nor individuals, even though some of the data were there. In one skeletal report (St. Mary Spital) tables showing the number of teeth present and number of teeth with caries in each tooth type were given, but the number of teeth present were only provided if there were teeth with caries in that group. Although the number of teeth with caries can be added up, lack of data on the number of teeth in the groups where no caries occurred made it impossible to determine the total number of teeth present, and so a total prevalence rate for that site could not be calculated. A similar approach had also precluded the collection of data from another London site, that of St Nicholas Shambles (White, 1988). In this case the skeletal catalogue gave the number of teeth present and with caries for each individual, but only if that individual had caries. The final type of inadequate data consisted of providing a prevalence rate without giving either the numbers of teeth present or with caries (Henley Wood; Franciscan Church Hartlepool). Although the prevalence rate gives information on the occurrence of caries at that site, and this can be compared with prevalence rates for other sites, these sites could not be included in the present study as the actual number of teeth present and with caries were required in order to combine data from more than one site.

7.3.2 The Skeletal Reports with Caries Data.

Even if a skeletal report did provide data on caries prevalence, this does not necessarily mean that the data were given in an easily accessible form. Several reports had not provided a numerical summary of the caries data, whether in tables or in the text, and only provided a descriptive comment, for example one skeletal report (Butler's Field) noted a "low incidences of caries… in the younger age groups" with a "dramatic rise" in older individuals; another (Little Eriswell) stated that "in a few individuals caries was present"; and yet another (Collingbourne Ducis) observes that "caries are present in the teeth of twelve individuals, five of whom were severely affected". In these cases the only option was to "trawl" through the skeletal catalogue (if one was provided) in order to try and collect data for each individual and then combine it to provide the required summary data.

Other situations also entailed compiling data from the skeletal catalogue, even if some data had been organised into a table or summary data given in the text. These included the provision of incomplete data, such as the number of teeth with caries but not number of teeth present, or teeth present and with caries for some groups of individuals but not others. It could also be necessary as a result of the provision of unclear data, which frequently occurred, where numbers in tables did not add up to the given totals or correspond with numbers given in other tables or in the text, or where it was unclear whether the numbers were for all permanent teeth or just those from adults. Some sites had sexed subadults and included them in the data for both sexes, again requiring the compilation of data from the catalogue to ensure that only adult individuals were included. Having to collect data from the skeletal catalogue was extremely time consuming, and it was even more inconvenient if the catalogue was on microfiche. It could only be done if the required information (teeth present and teeth with caries) was included for every single individual in the catalogue. If a vague entry for just one individual was given then this negated all the other entries where the actual numbers were stated. If, despite all efforts to resolve ambiguities, the uncertainty remained then the data from that skeletal report were not included in the analysis. However, since almost all reports had some kind of problem with the data the large majority of them would have been excluded unless some degree of doubt was tolerated.

In all, the information needed for a third of the data-sets used in this study (18 of 53) had to be collected from skeletal catalogues because unsatisfactory data was available in the main report. Occasionally a report would give the caries prevalence rate along with either the number of teeth present or number of teeth with caries. This happened in four reports, affecting five data-sets. In these cases the two figures given could be used to calculate the missing number, but this again increases the potential for error. The result was that barely more than half (30 of 53, 56.6%) of the data-sets used in this study actually had useful data on caries prevalence provided in summary form in the report, either in the text or in a table. This proportion drops to a third if all the data-sets for which data were collected are considered: 30 of 88, 34.1%. However, even though these sites may have provided summary data, it was not always present in the main report. In some cases the detail of the report was included on microfiche with generalised comments in the main text (for example: Castledyke South, Raunds, and Linlithgow). At other times the unpublished version of the report was found to contain more in the way of data than the published version (for example, Burgh Castle).

7.3.3 Discrepancies and Errors.

Even if a skeletal report had included a summary of the caries data there would frequently be discrepancies that needed to be resolved. There were numerous instances where numbers in a table did not add up to the total given. At other times the numbers given in different tables did not agree, or the numbers quoted in the main text were different from those given in the tables. Some of these differences were small, and had little effect on the calculated caries prevalence. For example, in one skeletal report (Spitalfields Market) the table providing data on the number of teeth present actually added up to 3159, and not 3158 as given in the table total. This difference was so small that it had no effect on the calculated caries prevalence – whether the total teeth numbered 3159 or 3158 the caries prevalence remained at 9.2%. In another report (Chichester) 33 errors in summing the number of teeth present in one table were noted, with a greater difference between the overall total given in the table (4222) and that obtained from adding up the numbers given in the table (4211). In fact, virtually every single table in this report relating to the dentition had numerous errors of summation, a fact which is even more inexcusable given that the tables were obviously prepared in a spreadsheet. Furthermore, the numbers in tables that were supposedly referring to the same base data often did not correspond. Inconsistencies of this magnitude are virtually impossible to resolve satisfactorily without reference to the original material. This same report also refers to a certain number of the adults with dentitions as being male or female in the text, but a detailed study of the tables on which these statements were based revealed that a number of these male and female 'adults' actually included sexed subadults. Without paying careful attention to the detail, and double-checking numbers, it would be easy to take the figures quoted in the text as they stood.

However, occasionally the enormity of the error was much greater and had more serious consequences for the caries prevalence. The skeletal report for Norwich Castle states that 46 of the 1767 teeth from adults were carious, giving a prevalence rate of 2.6%. This prevalence rate has been quoted elsewhere as being quite low (for example, Mays, 1996: p28; Anderson, 1990: p11). On studying the report carefully it transpires that these 1767 teeth are supposed to come from the 41 adults with surviving dentitions, but 41 adults, even if they had all their teeth, cannot possibly have had more than 1312 teeth (41 x 32) and the report states clearly that a number of teeth were missing postmortem, ante-mortem or were unerupted. The figure for the number of teeth present had actually been obtained through counting the number of separate mandibles and maxillae present, giving a total of 67 (half-) jaws, and then multiplying this total by 32 (effectively doubling the number of teeth expected) and then subtracting from this total the number of teeth that were not present. As the data given in the report were plainly in error, the data on dental caries given in the skeletal catalogue were compiled. This produced a total of 750 permanent teeth from adults, with 52 carious, giving a prevalence rate of 6.9% - considerably higher than that previously given in the report! However, the calculation of this new prevalence rate assumes that the data given in the skeletal catalogue are accurate, and without the original skeletal material this is impossible to check.

7.3.4 Issues of Comparability.

Although data on dental caries could be obtained from the skeletal reports for 85% of the data-sets, the type of data provided varied considerably. Some reports had reported the prevalence of caries in skeletons, others the prevalence of caries in teeth, and yet others had provided data on both. Caries prevalence in teeth was preferred by most authors, with 91.9% of the data-sets with some form of caries data having data in this form, compared to the 75.7% of the data-sets that had data on caries prevalence in individuals. Obviously, these two ways of reporting caries prevalence are not comparable; it would be meaningless to compare a site where 40% of the individuals had caries with a site where 7% of the teeth had caries. Only 67.6% of the data-sets had data for both teeth and individuals available, so those where no data for teeth had been provided had to be excluded.

The problem with reporting caries prevalence as the proportion of individuals affected is that this assumes that all individuals in the collection have a complete dentition preserved, but archaeological skeletons are invariably damaged and incomplete (Mays, 1998; Roberts and Manchester, 1995; Waldron, 1994a). Teeth are often dislodged from the jaws, or damaged, whilst the skeleton is in the ground, during excavation and post-excavation processing (cleaning, packing, marking) or at any point the material is handled, for example for recording and analysis (Hillson, 2001; Mays, 1998; Roberts and Manchester, 1995; Caffell, *et al.*, 2001). In addition, individuals may lose teeth during life for a variety of reasons (Hillson, 2001; Brothwell, 1963). There is no way of knowing whether these missing teeth had caries or not, and so it cannot be determined whether or not an individual suffered from caries if none of the remaining dentition display carious lesions. This measure of dental caries is likely to underestimate the true prevalence rate.

The alternative is to provide caries data as the number of teeth with caries divided by the number of teeth present, as this is more likely to provide a true approximation of the prevalence rate (Roberts and Manchester, 1995). However, this approach does not take account of the fact that single-rooted, anterior teeth are more likely to be lost postmortem than the multiple-rooted posterior teeth. Since caries is more likely to occur in the molars this practice may imply a higher caries prevalence than was present originally (Hillson, 2001, 1996). One option would be to compare caries prevalence according to tooth position, but few skeletal reports have presented data in this way. Overall ten (18.9%) of the 53 data-sets used in this study have provided data on number of teeth present and number of teeth with caries for each tooth position. Four of these data-sets were for the Early Medieval period and six for the Late Medieval period, with none for the Middle Medieval period. In addition, one skeletal report (Isle of Ensay) had divided the teeth into anterior and posterior teeth. Ironically, on one occasion (Taunton Priory), a data-set with detailed data on dental caries had to be excluded, as there were no data given for the overall prevalence rate in the teeth and this could not be determined from the data given.

Even though 91.9% of the data-sets where caries data had been provided had given the data as prevalence in teeth, the type of tooth selected varied. Some reports had given caries prevalence in teeth from adults and others in permanent teeth, with more providing data for the former than the latter. As the permanent teeth begin to erupt from the age of approximately six years old and onwards, the latter calculation will have included teeth from subadults. Since caries prevalence increases with age (Hillson, 2001), including teeth from subadults will likely provide a lower caries prevalence than will restricting the calculation to just teeth from adults, and just such an effect was observed when the two prevalence rates were compared in samples where both had been given. Ambiguity as to which of these two groups of teeth were being studied was encountered in some of the reports where the term 'adult teeth' had been used without making it clear whether they were referring to 'permanent teeth' or 'teeth from adults'. Some of the reports had stated that they were providing data on caries prevalence for sexed adults only, but others included the unsexed adults, and others did not specify whether unsexed adults were included or not. Several people have stated the importance of recording data for each sex separately (for example, Hillson, 2001; Roberts and Cox, 2003; Roberts and Manchester, 1995), yet a considerable number of the skeletal reports read during the course of this study had not done so (around 40% of those data-sets that had data given on caries prevalence in teeth had not provided data for both sexes). Even more reports (c. 60% of those with data on caries prevalence in teeth) had neglected to provide any data on caries prevalence in teeth from subadults, whether deciduous, permanent, or both. O'Sullivan *et al.* (1993) have noted the paucity of studies on caries in subadult teeth from archaeological populations, and research in this area is unlikely to be encouraged if few skeletal reports are concerned with providing the raw data. There seems to be a general assumption that caries was rare, if not non-existent, in the teeth of subadults in the past, which has perhaps precluded the detailed recording of subadult caries prevalence from archaeological sites. It could also be related to issues concerning the difficulty of measuring caries rates in a mixed dentition. Recording is complicated by the natural exfoliation of deciduous teeth, and the eruption into the mouth of the permanent teeth. In an archaeological specimen it is harder to determine at what point a tooth has become exposed to the environment of the mouth and so placed at risk of developing caries. Deciduous teeth are much smaller than their adult equivalents, and less firmly held in place in the jaw, which, being smaller and more fragile is more prone to being damaged with associated loss of the teeth.

7.3.5 Trends in Data Presentation.

Because of limitations inherent in the data available, analysis had to be restricted to 60% of the original number of data-sets for which data were collected. The fact that more of the Late Medieval data-sets had comparable data had the effect of reducing the discrepancy in sample size (in terms of number of data-sets) between the Early and

Late Medieval periods. Although the number of selected data-sets for the Early and Late Medieval periods was similar, the Late Medieval sample consisted of data for considerably more skeletons than the Early Medieval sample. There was a tendency for the caries data for the Late Medieval data-sets to be better (or more consistently) presented. Compared to the Early Medieval data-sets, a higher proportion had provided usable data and a higher proportion of these had actually given these data in summary form, meaning that fewer had to be collated from the skeletal catalogues. In addition, a higher percentage of the Late Medieval data-sets had also provided data according to tooth position, although fewer had given data on caries prevalence for teeth in different age groups. The possible reasons for this discrepancy are explored below.

More of the Early Medieval data-sets used in this study had been published (19 of 23, 82.6%) compared to the Late Medieval data-sets (12 of 21, 57.1%), and it is possible that the unpublished material tended to include more detail. As an example, the unpublished report for Burgh Castle included more detail on dental caries than did the published version. Interestingly, every single case where data had to be collated from the skeletal catalogue, or calculated from a prevalence rate given in the text due to inadequate data provided in the report, occurred in published data-sets: 12 of 12 Early Medieval, 4 of 4 Middle Medieval and 7 of 7 Late Medieval. Not all published data-sets were deficient – 15 (50.0%) of the 30 data-sets that did provide satisfactory data in summary form had been published. These figures could be misleading, as they are just those for the data-sets for which suitable data could be obtained; there were unpublished reports that did not provide suitable data at all. However, the implication is that the majority of published sources do not include adequate detail and this could reflect the restrictions on space in many publications (Roberts and Cox, 2003). In some cases the full report was placed on microfiche with a condensed version in the text, for example Castledyke South. This is not ideal as access to a microfiche reader is necessary in order to read the report, and there is the risk of microfiche films being lost, especially in library copies of books (this was experienced by the present author on more than one occasion). However, even if Waldron does believe that "this is the most certain way… of ensuring that it will never again see the light of day" (1994a: p58), placing the full version of the report on microfiche is preferable to not including it at all. Microfiche photocopiers exist, meaning that anyone genuinely interested in the report can make a paper copy that can be read at any location.

Another possibility is that since the majority of the unpublished reports were prepared at what was the Calvin Wells Laboratory in the University of Bradford (eight (53.3%) of the 15 unpublished data-sets used in this study) there was some degree of consistency in recording and presentation of data between these reports. Although different individuals were the main authors of the Bradford reports, the second author(s) invariably included one or other (or both) of two individuals. Even if they were not named as authors of the reports, their advice no doubt influenced the form of the report itself, and the main author probably used other reports prepared at Bradford as a guide. Since more of the Late Medieval data-sets were unpublished, including five reports prepared at Bradford, it is possible that some of the tendency towards full presentation of summary data in the Late Medieval sample can be accounted for by this fact. The remaining data-sets were associated with the Ancient Monuments Laboratory (n 3), the Museum of London Specialist Services (n 2), and the last two data-sets were not associated with any particular organisation.

The final possible explanation concerns date. Although the two dates will not necessarily be the same, the date the skeletal remains were excavated will provide a rough indication as to the date they were analysed and the report was written. In general, it seems as though those sites that were excavated earlier (and presumably studied earlier) were less likely to provide satisfactory data on dental caries than those that were excavated later, which is only to be expected as methods advance and knowledge of the problems with the analysis of skeletal remains develop. In addition, there has been an increase in the number of individuals trained in biological anthropology since the introduction of Masters-level courses in several academic institutions in Britain from 1990 onwards, for example at the University of Bradford (Caffell, *et al.*, 2001). For all periods, the majority of the total data-sets had been excavated in the 1970s and 1980s: Early Medieval = 23 of 41 data-sets (56.1%), Middle Medieval = 11 of 13 data-sets (84.6%), Late Medieval = 24 of 34 data-sets (70.6%). This was also true of the data-sets used in the study of dental caries: Early Medieval = 16 of 23 data-sets (69.6%), Middle Medieval = 9 of 9 data-sets (100%), Late Medieval = 15 of 21 data-sets (71.4%). However, none of the original 34 Late Medieval data-sets, and only one (7.7%) of the original 13 Middle Medieval data-sets, were excavated before the 1970s. In comparison, 11 of the original 41 Early Medieval sites were excavated during the 1950s and 1960s, plus one excavated during the 1920s, meaning almost a third (29.3%) of the Early Medieval data-sets had been excavated pre 1970s. Of the Early Medieval data-sets used in this study, six (of 23, 26.1%) had been excavated in the 1950s and 1960s, and data for five of these had to be collated from the skeletal catalogue. Of the remaining seven data-sets where data was collated from the catalogue, six were excavated in the 1970s or 1980s, and one in the 1990s. All the data-sets, bar one, where adequate summary data was provided were excavated in the 1970s or 1980s. In comparison, five of the Late Medieval data-sets were excavated in the 1990s (23.8%) and every single one of these reports provided adequate summary data. As the Late Medieval data-sets tended to be excavated later it was only to be expected that the quality of data presented in the reports would be that much better. However, this generalisation does not hold true for all data-sets. Good data presentation had occurred in several of the sites excavated in the late 1960s/early 1970s, and terrible data presentation has been observed in sites excavated during the 1990s.

7.3.6 Implications.

In summary, although a few reports displayed exemplary data presentation, in general the data on dental caries provided in the available published and unpublished skeletal reports was far from satisfactory. In some cases no data could be obtained, either because caries was not reported at all or because numerical data were not provided to accompany the descriptive comments in the text. In several cases the skeletal catalogue could be used to collect data where summary data were not given, or where such summary data was incomplete or unclear, but there were often problems in using this approach. Often the data in the catalogue did not match those in the main report, or the data might not be given in a consistent form for each individual throughout the catalogue. Finally, the data given in summary tables and in the text were often found to contain errors. Although some of these errors were comparatively small, others could be much greater and consequently had a larger impact on the data obtained.

In general these problems highlight not only the necessity for improved standards of data recording, but also for increased consistency in data presentation. Giving summary data in tables would be one means to achieve this, provided all reports included data for the same sets of criteria. The number of discrepancies currently present in reports necessitates a close scrutiny of the numbers reported, and undermines confidence in the accuracy of the work carried out. It also highlights the amount of care required when quoting numbers given in skeletal reports, or attempting to use them as the basis for a comparative study. The implications for the present study of the quality of the data available included a reduction of the number of data-sets it was possible to include, and restrictions on the type of data it was possible to compare between data-sets. With few reports giving detailed data on dental caries, comparison had to be made at the most basic level. This will affect the value of the information gained, as more informative conclusions could have been drawn from better caries data. However, it is hoped that the general trends identified in this thesis will suggest areas where future, more detailed, work can be carried out.

7.4 The Age Division Between Adults and Subadults.

A degree of variation, ranging from 15 years to 20 years and over, was observed in the age used to separate the adults and subadults in the data-sets used for this study. The implications of this variation for the present study, or for other projects comparing caries prevalence data between sites, is that the caries prevalence rates compared will not, strictly speaking, be exactly the same. Caries has a tendency to increase in frequency with age (Mays, 1998), so a sample that includes younger individuals than another sample will be expected to demonstrate a lower caries prevalence. This trend was observed in the present study when the caries prevalence rate in the permanent teeth was compared with the prevalence rate seen in the teeth from adults in the same data-set. The permanent teeth tended to have a lower caries prevalence rate than the adult teeth, which is expected, as some of the permanent teeth in the sample are likely to have come from subadults. The data-sets where younger individuals were included in the 'adult' group are therefore likely to have a slightly lower caries prevalence rate than a sample where the definition of 'adult' excluded these younger individuals. This is a point that should be considered when caries prevalence rates from different sites are compared. However, for this study the only option was to accept the age-at-death data as they were given in the skeletal reports, however inconsistent they might be, but to be aware that this imposed another limitation on the reliability of the results obtained.

7.5 Proportion of Aged Individuals.

A trend noticed during analysis of the data was that the proportion of males and females that could be aged was often higher than the proportion of adults in general that could be aged. This pattern was observed for all samples, with the exception of the Middle Saxon Males, the Early-Late Medieval females, the Late Medieval Benedictine males and Gilbertine females, three of the Early Medieval regions (Far North males and females, Central Southern females, and South East males) and North/North West females of the Middle Medieval Regions. The most reasonable explanation is probably related to preservation. If a skeleton is well enough preserved for an estimation of sex, then it is more likely that the relevant skeletal elements are present and in a suitable condition to estimate age at death, and therefore it should be expected that a higher proportion of sexed adults could be aged.

7.6 Chronological Division.

7.6.1 Medieval Main Periods: Early Medieval; Middle Medieval; Late Medieval.

As has already been noted above, the Late Medieval sample consisted of a larger number of skeletons, with a mean of 257.6 skeletons per data-set, compared to the Early Medieval mean of 108.5 skeletons per data-set and Middle Medieval mean of 151.3 skeletons per data-set. The largest number of skeletons in an Early Medieval data-set was 222, compared to 363 (Middle Medieval) and 1605 (Late Medieval). In addition, the proportion of data-sets comprising over a hundred skeletons rises with each period: Early Medieval = 52.2% (12 of 23), Middle Medieval = 55.6% (5 of 9), Late Medieval = 61.9% (13 of 21). This trend is even more noticeable if the total data-sets are considered: Early Medieval = 46.3% (19 of 41), Middle Medieval = 53.8% (7 of 13), Late Medieval = 64.7% (22 of 34). In fact, five of the total Late Medieval data-sets have over 500 skeletons (with two containing over a thousand).

All these figures show that the size of skeletal collections available increases through time over the periods studied, so those of the Late Medieval period tend to be larger than those of the earlier periods. There are various reasons why this should be so. The earlier sites could be less well preserved than the later ones, resulting in fewer skeletons surviving to be excavated, or perhaps the earlier Medieval cemeteries were less completely excavated. Burial in different soils with varying pH levels, the degree of waterlogging, the depth of burial, and amount of disturbance by animals or plant roots all affect the preservation of bone, but after material has been in its burial environment for a while a degree of equilibrium is established and the decomposition process is slowed considerably (Janaway, 1996; Garland and Janaway, 1989; Henderson, 1987). There is no evidence to suggest that the Early Medieval sites were particularly badly preserved in comparison with the Late Medieval sites; although they did have a slightly higher proportion of unaged individuals (in total) and unsexed adults these proportions were not that much higher than the other periods, and the proportion of Aged Adults was the same as that for the Late Medieval period. There is also no reason to believe that the Late Medieval cemeteries were excavated in their entirety more often than the Early or Middle Medieval sites. The most likely explanation for the increase in sample size is that the Late Medieval cemeteries were mainly located at urban sites, therefore serving a larger population, and they were also in use for longer periods of time (see Figure 5.2:2 and Figure 5.5:2), thus accumulating more burials. In addition, urban sites are more likely to be excavated than rural sites, reflecting modern development (Hunter, *et al.*, 1993), although the fact they are urban may mean they are less likely to be excavated in their entirety. However, the Late Medieval rural data-sets tended to have a smaller number of skeletons compared to the urban sites. The Early Medieval sites were all serving a rural population, and the Middle Medieval sites contained a mixture of some rural and some urban, with a few sites in the process of becoming a small town. This could account for the intermediate position of the Middle Medieval period in terms of trends in cemetery size.

7.6.1.1 Proportions of Adults and Subadults.

In the Early and Late Medieval periods, adults made up roughly 70%, and subadults 30%, of the sample, but there were proportionally fewer adults in the Middle Medieval sample. In past populations, as in populations from developing countries, a high mortality rate amongst infants and children is usually expected (Roberts and Manchester, 1995; Daniell, 1997), for example, in Victorian Britain infants made up around 25% of all deaths (Wohl, 1984; Howe, 1997). Therefore a reasonably high percentage of subadults are anticipated when archaeological cemeteries are excavated. Saunders *et al.* (1995a) found that subadults (below the age of 15) made up 50.5% of the sample excavated from a nineteenth century churchyard in Canada, but this was higher than the proportion expected from analysis of the parish records. Conversely, Scheuer and Bowman (1995) found that subadults (below the age of 18) comprised only 10.5% of the eighteenth-to-nineteenth century sample from St. Bride's Crypt, London, whereas the proportion of child burials in the crypt as a whole was 27.9% and parish records showed that children made up 40.5% of the deaths; children were also underrepresented in the crypt sample from Christ Church, Spitalfields, London (Cox, 1995). This problem of under representation of subadults has often been attributed to poor preservation of subadult bones in comparison to the larger and more robust bones of adults (White, 1988), or to shallow burial of subadults (Evison, 1987). However, Saunders *et al.* (1995b: p77) suggest that this "lack of subadults in many archaeological collections is more likely due to differential burial practices and inexperienced or biased excavation". Such variables in burial practice, for example, burial of children beneath the eves of the parish church or exclusion of unbaptised infants from the church cemetery (Daniell, 1997), will reduce the number of children in the sample if the area of the cemetery containing the concentration of child burials is not excavated. Waldron (1987b) has demonstrated that smaller bones are less likely to be recovered during excavation due to lack of awareness on the part of the excavator, a fact which is also likely to affect the retrieval of subadult bones, especially if trained osteologists are not involved with the excavation of the site.

It is difficult to know what proportion of subadults should be expected in an archaeological sample, especially since the factors that may influence the mortality of subadults and their inclusion in the cemetery probably varied between populations. Additionally, variations in fertility and patterns of population migration can have a greater impact on the proportion of subadults present in a cemetery sample than mortality patterns (Wood, *et al.*, 1992). White (1988: p30) has suggested that subadults should make up 30-50% of deaths in a "pre-industrial society with low standards of hygiene and nutrition". The proportions present in the data collected and pooled for this study are consistent with the lower end of this estimate, as subadults make up approximately 30% of the sample in both Early and Late Medieval periods and 35% in the Middle Medieval period. Moreover, since the majority of other sub-divisions of the data also show a proportion of subadults similar to 30% this might be the 'normal' proportion to be expected in Medieval Britain. Obviously, the pooled data ignores variation that occurs within individual cemeteries, but overall subadults do not appear to be particularly under-represented in any period. However, the detailed age distribution of individuals within the 'subadult' category is unknown, so it is not possible to assess the proportions of infants and younger children against the proportion of older children and adolescents, and the upper age limit for the category has varied between 15 and 20 years in different skeletal reports (see Section 7.4).

7.6.1.2 Sex Distribution.

The Early Medieval sample had an equal sex distribution, suggesting that the sample represented a cross-section of the population. In contrast, the Middle and Late Medieval periods consisted of a larger proportion of males. The discrepancy between the sexes was particularly large in the Late Medieval period, and the sex distribution of this period was significantly different from both earlier periods. Walker (1995) has suggested that since the skeletons of females are often more gracile than those of males, and that females may be more prone to loss of bone density with age, that in some circumstances female skeletons may be less well preserved than those of males. If this were the case then the skeletal elements required for sex assessment may be missing or damaged, and these poorly preserved female skeletons might be classed as 'indeterminate'. He also suggests that elderly females are often misclassified as males based on the heavier supra-orbital ridges often present in older women, a fact also discussed by Meindl *et al.* (1985a). These might both be reasons to account for a surplus of 'males' in a sample, although the balance ought to be redressed if younger males are mistakenly identified as female because they are more gracile (Walker, 1995). However, the Late Medieval sample consisted of a large number of monastic and hospital sites, both of which showed a tendency towards a high proportion of males (see Section 7.7.1.2). It is likely that this is the reason for the uneven sex ratio in the Late Medieval sample overall. The number of males and females in the Middle Medieval period were found to be significantly different from that normally expected, but only at the 2.5% level, and they were not found to be significantly different from the number of males and females in the Early Medieval period. The Middle Medieval sample only contained one monastic site, which is unlikely to have had a large impact on the overall sex distribution. It is possible that the smaller sample size of the Middle Medieval period has resulted in a biased sex distribution.

7.6.1.3 Age Distribution.

7.6.1.3.1 Adults in General.

Bearing in mind the general unreliability of age-at-death data available in skeletal reports, the age distributions are summarised to facilitate comparison of caries prevalence between the different groups but the reasons for variation between samples are not discussed in detail. The age distribution of the samples was significantly different between all three periods. The Late Medieval sample had a slightly higher proportion of individuals in the two older age categories at 50.5%, but the Early Medieval sample had the highest proportion of individuals in the Old Adult category. The Late Medieval sample had the smallest proportion of individuals in the youngest age group, with the Middle Medieval sample having the largest.

7.6.1.3.2 Adults: Male and Female Subdivisions.

There were no significant differences between the age distributions of the males and females in any of the three samples, although for both the Early and Middle Medieval samples there was a tendency for a higher proportion of females to be found in the Young Adult age group and a lower proportion in the Old Adult group compared to males. The usual explanation for a higher proportion of females in the younger adult age groups is that of the risks of pregnancy and childbirth (for example, see Rogers, 1984). Whilst death in childbirth no doubt occurred (Wells (1988) has described a situation where a small woman with android skeletal features possibly died when giving birth to a large baby), it is unlikely that it resulted in a considerably higher death rate among young women than occurred in young men; Roberts and Cox (2003) found little evidence of death in utero during their recent survey of British skeletal reports. Walker (1995) has pointed out that small biases in sex estimation error (mistaking a few young males for females and older females for males) can create age distributions where it appears that women are dying younger and males older, and the classic childbirth argument is proffered as an explanation.

7.6.1.4 Caries Prevalence.

7.6.1.4.1 Teeth From Adults.

The caries prevalence rates for teeth from adults were significantly different between each main period (see Table 6.3:7). The Early Medieval period had the lowest caries prevalence (5.0%), the Late Medieval period had a higher caries prevalence (8.3%), but the highest prevalence was observed in the Middle Medieval period (9.2%).

Several studies of caries prevalence in Britain have shown that caries prevalence was particularly low during the Early Medieval period, but increased in the Late Medieval period (see Table 7.6:1), and the data from the present study are consistent with this finding. In comparison with the results from other studies, the Early Medieval prevalence of 5.0% fits in the middle of the values previously reported; it is lower than those reported by Brothwell (1959), Hardwick (1960), and Freeth (1999), but higher than those observed by Roberts and Manchester (1995) and Roberts and Cox (2003); it is also higher than the data reported for Scotland alone (Lunt, 1986) and Ireland (Power, 1993). However, these results are not strictly comparable, as the majority of these studies appear to have reported caries prevalence in permanent teeth, which is likely to have resulted in a lower caries prevalence than that obtained from adult teeth. This could partly account for the lower prevalence observed by Roberts and Cox (2003) even though they also compiled data from many of the same published and unpublished reports. They were also able to include more data-sets in their study.

Table 7.6:1 Studies of Caries prevalence in Medieval Britain - a comparison.

Study	Caries Prevalence (% permanent teeth carious)	
	Early Medieval	Late Medieval
Britain		
Brothwell (1959) ❶	c. 6%	c. 14%
Hardwick (1960)	8.10%	-
Roberts & Manchester (1995) ❷	3.40%	7.00%
Freeth (1999)	7.20%	11.50%
Roberts & Cox (2003)	4.20%	5.55%
This Study ❸	5.0%	8.3%
Scotland		
Lunt (1986)	4.32%	6.00%
Ireland		
Power (1993)	3.90%	-

❶ percentages taken from a graph, so approximate values only

❷ percentages calculated from the raw data given in Table 4.1, p 49

❸ % adult teeth carious

Fewer studies had reported data for the Late Medieval period, but again the results of this study sit in the middle of the results previously obtained, again being higher than the results of Roberts and Manchester (1995), Roberts and Cox (2003), and Lunt (1986), and lower than the results of Brothwell (1959) and Freeth (1999). The largest difference in caries prevalence between the two periods occurred in the data presented by Brothwell (1959); the smallest difference between the two periods was found in the data given by Roberts and Cox (2003) and Lunt (1986). The present study showed a difference of 3.3% between the two periods, which was closest to the differences present in Freeth (1999) and Roberts and Manchester (1995).

There are no data with which to compare the Middle Medieval period, but the prevalence rate of 9.2% was unexpectedly high. It had been anticipated that this group would show a caries prevalence intermediate between those of the Early and Late Medieval periods, but it was actually significantly higher than that of the Late Medieval Period. Following inspection of the individual data-sets, it is suggested that the prevalence rate for the adult teeth of this period has been skewed by the high prevalence rate for Trowbridge. This data-set had a caries rate of 24.3% (see Appendix 6), which was much higher than the site with the next highest prevalence rate (Rivenhall B, 15.9%), and also higher than the caries prevalence reported for a skeletal collection of low socio-economic status excavated from an eighteenth-to-nineteenth-century cemetery in New Orleans, North America (22.3%), where the diet included highly cariogenic foods such as cane sugar, molasses, and finely ground corn flour (Owsley, *et al.*, 1987). Even though Trowbridge became the centre of a feudal complex in the early twelfth century and so may have been a site of reasonably high status (Graham and Davies, 1993), it is difficult to envisage how this population would have obtained a diet substantially more cariogenic than that consumed by the populations of other high status sites of the period, or, for that matter, than that consumed in nineteenth century New Orleans. A combination of other factors peculiar to the population of that one site could have combined to produce such a high prevalence rate, but on balance this seems unlikely. Without access to the original skeletal material it is difficult to be sure whether the Trowbridge prevalence rate is genuinely high, or whether caries has been over-diagnosed. If the data for Trowbridge is excluded from the calculation then the prevalence rate for the Middle Medieval adult teeth is 5.8%, which would mean that the caries prevalence of the Middle Medieval period was slightly higher than that of the Early Medieval period.

Each period had a significantly different age distribution from the other periods, so it is possible that this has affected caries prevalence. The slightly higher proportion of individuals in the two older age groups (compared to the other two periods), and small proportion in the Young Adult category, in the Late Medieval group might have contributed to the higher caries prevalence observed in this sample, but a quarter of the individuals in the Early Medieval sample are found in the Old Adult category. The high proportion of individuals in the two younger age groups of the Middle Medieval period would be expected to produce a lower caries prevalence, yet this was the sample with the highest prevalence rate. However, this high prevalence is probably the result of bias introduced by one sample.

The low caries prevalence observed for the Early Medieval sample suggests that the diet was not particularly cariogenic, a conclusion that has been drawn by others (Brothwell, 1959; Hardwick, 1960; Moore and Corbett, 1971; Freeth, 1999; Roberts and Cox, 2003). During this period the majority of the population would have been consuming locally produced food, with cereals (wheat, rye, barley and oats) in the form of bread, pottage and ale forming a large part of the diet (Hagen, 1992, 1995; Reed, 1990; Fowler, 2002; Hinton, 1990). Some pulses, vegetables, fruit and berries would have been available, supplemented with dairy products from cattle, sheep and goats. Meat and fish were also consumed, but perhaps not in large quantities by the poorest sections of society (Fowler, 2002). However, stable isotope analysis on the skeletons from Berinsfield, Oxfordshire have shown that animal proteins were eaten by the whole population, although the form in which this protein was consumed, or the quality of the food, cannot be determined (Privat and O'Connell, 2002). Honey would have been the main sweetening agent, but it might not have been that abundant (Hagen, 1995).

This diet is high in carbohydrates, but since they were not refined and most bread consumed was coarse (Hagen, 1992), the risk of caries development is small. Unrefined and uncooked carbohydrates have been associated with low caries prevalence in populations in Nigeria (Enwonwu, 1974) and Amazonian Brazil (Rebelo Viera, *et al.*, 2002), although the latter authors note the potential for increased cariogenicity of cassava flour exists if it is processed. Boiling cereal grains into a mush, perhaps in the form of pottage, may well have increased the cariogenicity of the foods available in the Early Medieval period, especially if combined with some form of sugar. However, the latter was only available in the form of honey, fruits and berries. The intrinsic sugars in fruits and vegetables would have been less harmful than the non-milk extrinsic sugars in honey. Proteins are not cariogenic since they contain no carbohydrates, and dairy produce is actively cariostatic, so the presence of these foods in the diet would be beneficial to teeth.

The coarse texture of the Early Medieval diet has often been cited as a reason for the low caries prevalence of this period, and is attested by the heavy attrition of the teeth observed in most Early Medieval populations (Brothwell and Brothwell, 1998; Moore and Corbett, 1971). Some have argued that this attrition has contributed to the low caries prevalence through wearing away the vulnerable pits and fissures and cleansing the teeth (Moore and Corbett, 1971). In addition, it is suggested that the particles of food are too large to enter any crevices, instead accumulating around the necks of the teeth (Moore and Corbett, 1971). These two factors could explain the low prevalence of caries in the occlusal surfaces and the predominance of lesions at the cemento-enamel junction. However, heavily worn teeth may become vulnerable to chipping and fractures, the pulp cavity may become exposed, and the raised rim of enamel surrounding the exposed dentine could also act as a focus for food accumulation, factors that might increase the risk of caries development. Freeth (1999) has suggested that the role of heavy attrition in caries prevention has been overstated, and that the stimulation of saliva by the coarse diet is far more important. This would be consistent with studies of modern populations that have shown an increased salivary buffer effect in individuals consuming a diet high in fibre requiring a lot of chewing (Mazengo, *et al.*, 1994). It appears that the fibrous nature of the Early Medieval diet, consisting as it did predominantly of foods with low cariogenicity, is responsible for the low caries prevalence observed. The carious lesions that did occur could indicate the processing of starchy foods in a way that made them more cariogenic, the presence of a small amount of natural sugars in foods, or poor oral hygiene. However, low caries prevalence has been observed in populations consuming a similar diet and not practicing oral hygiene (Enwonwu, 1974). An additional risk factor could be undernutrition resulting from an inadequate diet, a factor that has been associated with increased caries experience in clinical studies (Enwonwu, 1974; Moynihan, 2003; Williams and Curzon, 1986).

The higher caries prevalence of the Late Medieval period implies that the diet was more cariogenic than that of the Early Medieval period. Cereals (wheat, rye, barley and oats) were still the main dietary staple (Drummond and Wilbraham, 1957), but the wealthier classes consumed more white bread made from more finely ground and sieved flour and the poorer classes aimed to emulate them; certainly towards the end of the Late Medieval period finer wheat bread was generally consumed more often than the coarser rye bread (Dyer, 1989). This favouring of refined carbohydrates would have increased the cariogenicity of the diet and perhaps contributed towards the higher caries prevalence. A combination of carbohydrates with other foods in biscuits and cakes, or the enrichment of bread with honey and dried fruits for special occasions (Hagen, 1992; Black, 1992) would also increase the cariogenic potential of the diet. In addition, the enhanced salivary buffering effect observed in individuals consuming a coarse high-starch diet might have been lost to some extent (Mazengo, *et al.*, 1994). Vegetables, legumes, pulses and fruits all continued to be eaten, although Drummond and Wilbraham have commented on the apparent lack of vegetables in the diet (Drummond and Wilbraham, 1957) and this may be a bias introduced by documentary sources. Meat and fish were again available in greater quantity and variety to the wealthy, but the poorer classes were still able to afford some dried and salted cod and herring, and perhaps pork or bacon (Dyer, 1989, 1998, 2000). Cheese, milk and other dairy produce appear to have been consumed in reasonable quantity by the poor, and perhaps because of this were not regarded as desirable foods by the wealthy (Dyer, 1989). Cheese and milk in particular would have protected against the development of caries, and it seems that the poor benefited more from these foods than did the wealthy.

For much of the Late Medieval population local foods would still have provided the basis of sustenance, but the development of towns and trade would have meant more opportunity to obtain foods from elsewhere, especially for the upper classes (Dyer, 1989, 1998, 2000). It is likely that sugar began to be imported during the Late Medieval period, although the exact date this occurred is unclear. Sugar was supposedly amongst the spices left by Bede (AD 673-735) to be distributed amongst the brethren after his death, but references to sugar do not occur again until the Pipe Rolls of Henry II (AD 1133-1189) in the twelfth century (Hagen, 1995); in contrast, Hobhouse (1999) states that sugar did not reach Britain until AD 1319. It is possible that in the earlier centuries sugar was only available in tiny amounts and only to the wealthy but, that as the price dropped, increasing quantities were available to the rich and a broader section of the population was able to get access to it (Hobhouse, 1999). Even so, sugar was not generally affordable or available in quantity until the beginning of the eighteenth century (Galloway, 2000). The household accounts of a small manor house in rural Suffolk (AD 1412-1413) show that consumption of sugar was very low (Swabey, 1998), but this does show that some sugar was obtainable at this time by the gentry. The import of sugar is unlikely to have had a major impact on caries prevalence of the population in general in the Late Medieval period, but is more likely to have influenced the dental health of the wealthy. Other luxury foods that were likely consumed in higher quantities by the upper classes would have included sticky dried fruits, such as dates, raisins and figs, foods including larger quantities of honey, and pastries and sweetmeats. Honey was also used to preserve fruits and vegetables (McKendry, 1973). Some increase in the sources of sugar therefore occurred during the course of the Late Medieval period, although it is likely that most of these would not have been available to the general population on a regular basis. Those living in urban areas may have had more access to these, although the wealthy would have been able to transport goods to their rural estates.

The caries prevalence of the Middle Medieval sample (without Trowbridge) is only marginally higher than that of the Early Medieval period. This could suggest the implied change in diet of the Late Medieval sample had not begun, or was only just beginning, by the eleventh/twelfth centuries.

The Late Medieval sample is complicated by the fact that the skeletons come from a variety of contexts, and a considerable portion of the sites were monastic. The higher caries prevalence observed might simply reflect the large proportion of religious and wealthy secular burials present in the Late Medieval sample compared to the preceding periods. The demographic structure of the Late Medieval sample is certainly different from that of the Early and Middle Medieval periods, and this no doubt reflects the high monastic component of the sample. For this reason, the samples from different Late Medieval contexts are compared in Section 7.7, and chronological changes in caries prevalence within non-monastic and monastic groups are considered separately in Section 7.8.

7.6.1.4.2 Teeth from Adult Male and Female Subdivisions.

The male and female teeth show similar trends in caries prevalence to the adult teeth, with the Late Medieval samples showing a significantly higher caries prevalence than the Early Medieval samples. The difference occurs in the Middle Medieval sample, where the male and female teeth lie between the prevalence rates for the Early and Late Medieval periods, probably because Trowbridge did not provide data for teeth from sexed adults. In no period were there significant differences in age distribution between the sexes.

There were no significant differences in caries prevalence between the male and female teeth in the Early and Middle Medieval periods. This suggests that the cariogenicity of the diet did not vary between the sexes. The isotope study of the Early Medieval skeletal material from Berinsfield, Oxfordshire, found that no differences in diet could be identified (Privat and O'Connell, 2002). Where sex differences in caries prevalence have been observed in archaeological populations this is usually ascribed to differences in gender roles (for example, Walker, 1986), and other archaeological and documentary evidence has suggested that gender roles were strongly defined in this period (Privat and O'Connell, 2002). It is possible that these gender roles did not allow either sex preferential access to cariogenic (or cariostatic) foods. Another possibility is that since the Early Medieval diet was particularly coarse and required a lot of mastication, the females benefited more from the resulting increase in salivary buffering; Mazengo *et al.* (1994) observed that this buffering effect was significantly higher in females than in males, and it is possible that this might negate the caries difference that may be present otherwise. Although there were no significant differences between the sexes in the Middle Medieval period, female teeth do have a slightly higher caries prevalence (6.1%) than males (5.3%) and it is possible that this shows the beginning of the trend observed in the Late Medieval sample.

A significant difference in caries prevalence between male and female teeth was seen in the Late Medieval period, with the female caries prevalence (11.5%) being higher than the male (9.6%). If the diet had become less coarse then the salivary buffering effect resulting from heavy mastication might have reduced, and the female teeth would have been more greatly affected and become more vulnerable than male teeth to caries development (Mazengo, *et al.*, 1994). This interpretation would be consistent with an overall increased prevalence in caries due to an increased refinement of carbohydrates. Another reason for sex differences in caries prevalence could be related to the fact that females have a tendency to consume food more often, associated with their roles in food preparation: "Cooking and serving food to men as they do, women are accustomed all over the world to eating what is left over from dinner, they are often able, of course, to look out for themselves while preparing the meal" (Visser, 1991). Spending a large portion of time in the home can also encourage frequent eating, with meals tending to be shorter and more defined when they are consumed elsewhere, and it is often males who have greater opportunity for consuming food outside the home. However, it is unlikely that the female role in food processing, preparation and cooking has changed drastically from the Early to the Late Medieval period. Hagen (1992) observes that Early Medieval women were probably in charge of grinding grain, and were responsible for managing the food supply of the household, yet their caries prevalence was not significantly different from the male prevalence.

Other possibilities include an increased consumption of cariogenic foods by females, and the tendency for females to choose sweet and sugary foods has been documented in the clinical literature (Moynihan, 2003; Okullo, *et al.*, 2003; Åstrøm and Haugejorden, 2000). Perhaps amongst the wealthier classes any delicacies, such as sugared fruits, sweetmeats or pastries, were more often consumed by females. Cultural practices may have encouraged different behaviour relating to food choice in males and females. For example, Black (1992: p87) describes the process whereby upper class boys were sent to other households to learn "the more showy tasks such as displaying their skill in carving and their diet sense in ending a meal with cheese if they had a choice". Given its cariostatic properties, cheese would indeed be a sensible choice with which to end a meal, the implication being that females were not expected to show such restraint. Although from a later period, it is interesting to note that a Victorian etiquette book advised "young ladies" not to eat "cheese, nor game, nor savouries" for the sake of making their breath more pleasing to men (Visser, 1991: p279)!

Alternatively, females may have been restricted in the consumption of cariostatic foods such as cheese, or animal proteins, especially marine fish. Again there is evidence in other cultures of food prohibitions, such as Bengali girls being taught not to ask for additional fish, or the elaborate rules governing the parts of animals that may be consumed by men and women amongst the Tswana (Cook and Hunt, 1998). Such behaviour may have a physiological root: Cook and Hunt (1998) report than in modern North American populations women tend to choose diets containing less meat and foods of higher calorie-density than men even though culturally defined gender differences in access to food do not exist, and that such differences in diet are observed in primates. From this point of view, it is interesting to note that females from inland sites in the Late Medieval period had higher caries prevalence than those on the coast (whilst males did not), which could possibly indicate differential access to marine foods. Whether this is related to status is uncertain, as it is freshwater fish, not marine, that appears to have the highest monetary and status value (Dyer, 1988, 2000).

Any, or a combination, of these factors might be influencing the sex difference in caries prevalence seen in the Late Medieval period, and other unconsidered factors such as oral hygiene practices might also be contributing to the difference. A final point must be that the Late Medieval sample does contain a large number of monastic samples, which might have affected the caries prevalence rates observed in each sex in a different way.

7.6.2 Early Medieval Group Sub-Periods: Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon.

The overall sample sizes for both Group Sub-Periods were similar, and although the Early Saxon/Early-Middle Saxon Group had a slightly larger number of skeletons, it was made up of more data-sets, which had a lower mean number of skeletons per site (97.9 compared to 124.9 for the Middle-Saxon/Middle-Late Saxon Group). However, both groups had a similar proportion of data-sets containing over a hundred skeletons (ES/EMS = 7 of 14, 50.0%; MS/MLS = 5 of 9, 55.6%). Assuming there were no differences in completeness of excavation between the two groups, there do not appear to be any major changes in cemetery size, except perhaps a tendency for the data-sets in the later group to be slightly larger.

7.6.2.1 Proportions of Adults and Subadults.

Both Early Medieval Group Sub-Periods showed a proportion of adults and subadults very close to the 70:30 ratio discussed in Section 7.6.1.1 above. If this ratio is normal then this implies that a cross-section of the population is included in both groups and there are no major differences in burial practice (in terms of burial of children in cemeteries), preservation, or excavation between the Group Sub-Periods. It could also suggest that general patterns of child mortality remained similar from the earlier to the later period, that fertility remained the same, or that patterns of migration were unchanged.

7.6.2.2 Sex Distribution.

The sex distribution of the Early Saxon/Early-Middle Saxon Group Sub-Period was not significantly different from normal, but that of the Middle Saxon/Middle-Late Saxon Group Sub-Period was significantly different, with a higher proportion of males than expected. However, this difference was only significant at the 5% level, and the divergence from an even ratio was not that great. It is difficult to interpret these differences in sex distribution, especially as the pattern changes when the Divided Sub-Periods are considered. The data for the Group Sub-Periods might imply that a cross-section of the population is present in the earlier phase, but the higher than expected proportion of males in the later phase might be due to a variety of factors, including biases in preservation, excavation, or analysis. However, when the Group Sub-Periods are split, both the Divided Sub-Periods that make up the Middle Saxon/Middle-Late Saxon group do not, on their own, display a sex distribution significantly different from normal (see Section 7.6.3.2).

7.6.2.3 Age Distribution.

7.6.2.3.1 Adults in General.

There was a significant difference in age distribution between the two Group Sub-Periods. In the earlier Group Sub-Period there was a larger proportion of individuals in the two younger age groups, but the situation was reversed in the later Group Sub-Period.

7.6.2.3.2 Adults: Male and Female Subdivisions.

There were no significant differences in age distribution between the two sexes in either Group Sub-Period, and the distribution of each sex within the age categories was similar to that observed for the adults overall.

7.6.2.4 Caries Prevalence.

7.6.2.4.1 Teeth From Adults.

The Early Saxon/Early-Middle Saxon Group Sub-Period had significantly higher caries prevalence (5.7%), despite having a larger proportion of individuals in the two younger age categories, than the Middle Saxon/Middle-Late Saxon sample (3.6%). No other studies of caries prevalence in sub-divisions of the Early Medieval period have been made, so there are no other results with which to compare these data. These data suggest that a more cariogenic diet was consumed in the earlier period although, since both caries prevalence rates are low in comparison to those of the Late Medieval period, the diet cannot have been that cariogenic. Little data is available on differences in foods available, or any variation in food processing or consumption patterns that might have existed between the two periods. It is possible that some other factor is responsible for the difference, such as a bias present in the sample as a result of excavation or recording. Further sub-division of the Early Medieval period has been carried out in Section 7.6.3.

7.6.2.4.2 Teeth from Adult Male and Female Subdivisions.

The same trend as that observed for adult teeth is seen in the teeth for males and females, and there were no significant differences in caries prevalence, or age distribution, between the sexes in either group. The similarity in caries prevalence between the sexes implies that both consumed a similar diet.

7.6.3 Early Medieval Divided Sub-Periods: Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon.

The Middle Saxon group had the smallest overall sample size, and the Early-Middle Saxon group the largest, but this is simply a reflection of the number of sites available for each period. When the mean number of skeletons per data-set is examined there is little difference between the three later Early Medieval divided sub-periods: the Early-Middle Saxon sample has a mean of 125.8 skeletons per data-set, the Middle Saxon sample has a mean of 120.5, and the Middle-Late Saxon sample has a mean of 128.4. All three have a reasonable proportion of sites with over a hundred skeletons (EMS = 4 of 6, 66.7%, MS = 2 of 4, 50.0%, MLS = 3 of 5, 60.0%). In comparison, the Early Saxon sample had a much lower mean number of skeletons per data-set (77.0), with only 37.5% (3 of 8) of the sites having over a hundred skeletons, and it also had the smallest maximum number of skeletons in a single data-set (150, compared to 222 for the Early-Middle Saxon, 170 for the Middle Saxon and 197 for the Middle-Late Saxon samples). These figures imply that the cemetery size in the earliest phase tend to be smaller than those in the later periods (assuming no major differences in completeness of excavation). This may be related to the fact that the sites in this group appear to be in use for a shorter length of time compared to those in the other groups (see Figure 5.5:2), although this could also reflect the tighter dating resulting from the presence of grave goods. However, grave goods are also present in most of the Early-Middle Saxon sites, and although the earliest dates of these are not that much later than those for the Early Saxon sites, most continue in use for about an extra fifty to a hundred years.

7.6.3.1 Proportions of Adults and Subadults.

As with the Group Sub-Periods discussed above (Section 7.6.2.1), the proportion of adults and subadults remains close to 70:30 in each of the four Early Medieval Divided Sub-Periods. A slightly lower proportion of adults was found in the Early Saxon phase (66.6%) but, as well as a slightly higher proportion of subadults (32.0%), this group also had the highest proportion of unaged individuals (1.5% compared to the other Divided Sub-Periods, which ranged from 0.0% to 0.3%). It is possible that some of these individuals were adults, which would raise the percentage of adults slightly. Another possibility is that children in the pagan Early Saxon period experienced a slightly higher mortality than those in the later Early Medieval Divided Sub-Periods, or that no children were excluded from burial in the cemeteries, such as possibly occurred with the exclusion of un-baptised infants from later Christian graveyards (Daniell, 1997). Another possibility is that a small proportion of the adults were buried elsewhere (perhaps in the cremation cemeteries such as Spong Hill), or were given another type of funerary ritual that did not result in burial within a cemetery. Alternatively, the bias could result simply from slight variances in preservation or excavation, or be due to chance, and since the difference observed is not pronounced, this seems the most sensible conclusion. This high proportion of subadult individuals appears to be contrary to the general perception that children are under-represented in early Anglo-Saxon cemeteries (Lucy, 1994), although the term 'subadult' used here represents all individuals below the age of roughly 15-20 years (depending on the definition applied in the skeletal report from which data were collected) and the detailed age distribution of these subadults is not known.

Overall it seems that although changes in burial practice from the mainly pagan Early Saxon period through to the later Early Medieval Divided Sub-Periods occurred, with Christian burial probably having a different social meaning to pagan burial (Lucy, 2000, 1994), these changes did not result in markedly different proportions of adults and subadults in the excavated skeletal sample. Again, this implies the presence of a cross-section of the population in cemeteries throughout the Early Medieval period.

7.6.3.2 Sex Distribution.

The Early-Middle Saxon sample was the only one of the four Divided Sub-Periods to show a significant divergence from an equal number of males and females. Unusually, as in most archaeological populations a higher proportion of males are found, this sample had a high proportion of females (58.9%). The even distribution in the other three Divided Sub-Periods would imply the representation of a cross-section of the population, but the excessive number of females in the Early-Middle Saxon sample is difficult to explain. As preservation bias is more likely to artificially reduce the number of females (Walker, 1995) it is possibly not due to variances in preservation, and this difference remains unexplained.

7.6.3.3 Age Distribution.

7.6.3.3.1 Adults in General.

Of the four Divided Sub-Periods, three had more adults in the two younger age categories combined, with the Early Saxon sample having the largest proportion of individuals in this age group. The only Divided Sub-Period to have more individuals in the older age categories was the Middle-Late Saxon sample, and the age distribution of this sample was almost a mirror image of that for the Early Saxon sample. The age distribution for the Middle-Late Saxon sample was significantly different from each of the other sub-periods.

7.6.3.3.2 Adults: Male and Female Subdivisions.

Within each Divided Sub-Period the age distribution of males and females was not significantly different from each other, and the distribution of each sex was similar to that described for the adults in total.

7.6.3.4 Caries Prevalence.

7.6.3.4.1 Teeth From Adults.

The highest caries prevalence (6.9%) was found in the Early-Middle Saxon sample which was significantly different from the other three Divided Sub-Periods. This sample was the only one to have a sex distribution that was different from normal, with a higher proportion of females than expected. Whether this is related to the high caries prevalence found in this sample is unknown, but the implications are discussed more fully below. The Middle-Late Saxon sample had caries prevalence significantly lower than all other Divided Sub-Periods (3.0%), even though this group had the largest proportion of individuals in the two older age groups. The caries prevalence of both the Early Saxon (3.9%) and Middle Saxon (4.3%) samples was similar to each other, and both had a large proportion of individuals in the two younger age categories, so these low caries prevalence rates might be attributed to the age distribution of the sample.

These data show that caries prevalence has fluctuated slightly throughout the Early Medieval period, although it is difficult to account fully for any differences in age distribution between the samples that may be affecting the results. This fluctuation suggests that variations in diet may have occurred throughout the period, and that a uniform availability of the same food types, in the same proportions and prepared for consumption in a similar manner, was not necessarily the case. This should not be unexpected given the length of time concerned (c. 600 years). Again, there are no data with which to compare these figures, and no detailed information on variations in diet that may have occurred. Most of the Divided Sub-Periods show a low prevalence that would be consistent with a diet of low cariogenicity. The only exception is the Early-Middle Saxon sample, where the caries prevalence approaches 7.0%. Is this a genuine reflection of caries prevalence in this period, or does this group contain a biased selection of sites? One of the sites in this period is Castledyke South, which, with its location on the banks of the Humber Estuary, was well placed for trade with Northern Europe. It was suggested that this site was the centre for the distribution of imports (Drinkall and Foreman, 1998), and if so it could have received some exotic foodstuffs that may not have been available to other areas at that time. However, the evidence from the burial ground did not suggest a particularly affluent population, and the caries prevalence was 5.8%, not particularly high in comparison with other sites in this group. Two sites stand out as having high caries prevalence rates: Apple Down (10.2%) and Collingbourne Ducis (11.1%). The point must be made that data from the skeletal collections of Apple Down, Castledyke South, and Norton were recorded for a recent PhD thesis, and although data are presented for permanent teeth rather than teeth from adults, in each case the caries prevalence is lower than that published in the skeletal reports (Jakob, 2004). To some extent this might be expected based on the tendency for a prevalence calculated for permanent teeth to be lower than that calculated for adult teeth only. However, the reported prevalence rate for Apple Down in the skeletal report is considerably higher than that recorded by Jakob (3.38%), which brings into question the reliability of the data.

7.6.3.4.2 Teeth from Adult Male and Female Subdivisions.

The Early-Middle Saxon sample was the only one to have a significant difference in caries prevalence between the sexes, and contrary to the usual findings in archaeological and clinical studies, the male teeth had a higher prevalence (7.6%) than the female teeth (5.9%). Although there were no significant differences in age distribution between males and females, the males did have a slightly greater proportion of adults in the Old Adult category, which may account for some of this discrepancy. This group was the only one to have significantly more females in the sample than would be expected; the others did not differ from a normal sex distribution. It is possible that this uneven sex distribution has affected caries prevalence in some way. It may be that the males present in the excavated skeletal collection are a biased sample of those in the population. Perhaps the older males are those of a particular status group, although whether high status in this period would have lead to increased consumption of a cariogenic diet, or result in access to cariostatic foods, is unknown. This sample was the only one in which the caries prevalence in male teeth differed significantly from that of the other three Divided Sub-Periods, being different from them all.

The pattern for female teeth was much more complex with more significant differences between individual periods. The rise in caries prevalence from the Early Saxon (4.3%) to the Early-Middle Saxon period (5.9%) was significant; the slight drop in the Middle Saxon sample (5.3%) was not significant, but the drop to the Middle-Late Saxon sample (3.2%) was significant. The impression gained is that the low caries prevalence found in both sexes in the Early Saxon sample rose significantly in the Early-Middle Saxon sample, with the male teeth experiencing a greater increment. However, whilst the male caries prevalence dropped significantly in the Middle Saxon period, the female prevalence remained high, only dropping significantly in the Middle-Late Saxon phase. This last phase seems to have a particularly low prevalence rate in comparison with the other periods, especially considering the high proportion of both males and females in the two older age groups. These fluctuations may relate to variations in diet between the sexes, but since little is known of what these might be these differences in caries prevalence cannot be explained at present. However, throughout the Early Medieval period within each Divided Sub-Period the trend has been towards similar caries prevalence between the sexes, which would imply that in general there was little variation in diet between males and females.

7.6.4 Middle Medieval Sub-Periods: Late Saxon, Early-Late Medieval.

The Late Saxon sample had nearly double the number of skeletons present in the Early-Late Medieval sample, even though the number of data-sets in each period was similar. This resulted in the Late Saxon data-sets having a higher mean number of skeletons (175.2 compared to 121.5). More of the Late Saxon data-sets had over a hundred skeletons (3 of 5, 60.0% compared to 2 of 4, 50.0%), and the maximum number of skeletons in a data-set was higher (363 compared to 286). These figures imply that the Late Saxon skeletal samples tend to be larger than those from the Early-Late Medieval sample. It is difficult to suggest reasons for this difference. Both periods contain a mixture of rural sites and those in the process of developing into larger towns and urban areas. In both periods the rural sites tend to be manorial estate centres, such as Raunds Furnells (Boddington, 1996), or important in other ways, such as North Elmham possibly being the centre for the Elmham See before it was moved to Thetford in 1071 (Wade-Martins, 1980). In both groups most of the sites are tightly dated and span no more than around two centuries, so differences in cemetery size do not appear to be the result of differences in length of cemetery use.

7.6.4.1 Proportions of Adults and Subadults.

The Early-Late Medieval sample had a 70:30 ratio of adults to subadults, and these proportions have been found throughout the Early Medieval period. Again, this would imply the representation of a cross-section of the population; that there were no biases in excavation; that childhood mortality was similar to that present in the Early Medieval period; or that the population was stable in terms of immigration/emigration and fertility. However, the proportion of adults in the Late Saxon sample was considerably lower at close to 60%, with the proportion of subadults nearing 40%. This could represent biases in preservation and excavation, where proportionally more children have been recovered than were originally present; it could suggest a change in burial practice; it could indicate an increase in childhood mortality; or alternatively it could be the result of changes in fertility, or perhaps indicate the migration of groups of the population. It is difficult to interpret what this finding indicates when there are so many factors that could have caused it.

7.6.4.2 Sex Distribution.

Both Middle Medieval Sub-Periods show similar sex distributions, with slightly more males than females, yet it is only the Late Saxon sample that is significantly different from a normal sex distribution, which is probably due to the larger sample size. Again, it is unclear why there should be slightly more males than females in the samples from these periods.

7.6.4.3 Age Distribution.

7.6.4.3.1 Adults in General.

Like the Late Saxon sample the Early-Late Medieval sample has a higher proportion of individuals in the two younger age groups, but this is more pronounced mainly because the proportion of individuals in the Young Adult age group is considerably higher. The age distributions of each Middle Medieval Sub-Period were significantly different from each other.

7.6.4.3.2 Adults: Male and Female Subdivisions.

In the Late Saxon sample proportionally more females were found in the two younger age groups than males, but the opposite trend was noted in the Early-Late Medieval sample, with a greater proportion of males in the two younger age groups. Despite these differences, in neither sub-period were the age distributions of the males and females significantly different from each other.

7.6.4.4 Caries Prevalence.

7.6.4.4.1 Teeth From Adults.

The caries prevalence of the Late Saxon sample (6.0%) was significantly lower than that of the Early-Late Medieval sample (14.9%). However, the latter included Trowbridge, and if this site is excluded (see Section 7.6.1.4) the Early-Late Medieval sample is 4.9% and no longer significantly different from the Late Saxon sample. Since the Early-Late Medieval sample has a higher proportion of younger individuals, especially in the Young Adult category, than the Late Saxon sample, this slightly lower caries prevalence might be expected. This implies that there were no differences in diet between the two groups.

7.6.4.4.2 Teeth from Adult Male and Female Subdivisions.

As in the majority of phases throughout the Early Medieval period the male (5.9%) and female caries prevalence (5.6%) was the same in the Late Saxon group. No significant differences in age distribution were noted, although there were more females in the Young Adult, and fewer in the Old Adult, categories than males. This similarity in caries prevalence suggests that the diet of both sexes was similar. In contrast, the caries prevalence rates for males (3.0%) and females (8.8%) in the Early-Late Medieval sample are significantly different. The trend in caries prevalence is the opposite of what might be expected given the age distributions, as more males are found in the younger age categories compared to females. The caries prevalence of both sexes was significantly different from the Late Saxon sample. The drop in male caries prevalence might in part be accounted for by the higher proportion of males in the younger age categories in the Early-Late Medieval sample compared to the Late Saxon sample. However, although a high proportion of the Late Saxon females are found in the two younger age groups combined, it also has a higher proportion of individuals in the Old Adult group, suggesting that the higher caries prevalence seen in the Early-Middle Medieval females is not due to obvious variations in age. This might indicate a change in diet that has affected the males and females differently, whilst leaving the overall caries prevalence largely unchanged, and it could be the beginning of the difference in caries prevalence between the sexes observed in the Late Medieval sample. However, the sample size involved is particularly small (being only two sites), and a larger sample would be desirable to investigate whether these trends are real or simply an artefact.

7.7 Cemetery Types.

7.7.1 Late Medieval Sites: Church, Monastic, Hospital and Cathedral.

A large proportion of the Late Medieval sample is made up of monastic cemeteries (10 of 21, 47.6%), so it is not surprising that this is the cemetery type represented by the most skeletons. Although the number of skeletons in the hospital sample is smallest, this group actually has the highest mean number of skeletons per data-set (223.7), and two of the three data-sets had over a hundred skeletons (66.7%), with the largest number of skeletons in a single data-set being 384. One of these data-sets actually comes from Spitalfields Market, London, where close to 11,000 skeletons have recently been excavated and are currently undergoing analysis; the data-set included here came from a detailed preliminary analysis of 200 of these skeletons and was produced to test recording methods and formulate research questions in advance of full analysis (Connell, 2002). The monastic sites also had a fairly high mean number of skeletons per data-set (168.9), and eight of the ten sites had over a hundred skeletons (80.0%), with the largest number of skeletons being 271. In comparison, although the church cemeteries also provided a substantial sample (1,445 skeletons), the majority of these came from a single site (St. Helen-on-the-Walls, York, 1037 skeletons). If this site is included, then the mean number of skeletons per data-set is high at 206.4, but only 2 of 7 sites (28.6%) contain over a hundred skeletons. By excluding St. Helen-on-the-Walls, the mean number of skeletons per data-set drops to just 68.0, leaving only one site (Isle of Ensay) with over a hundred skeletons (1 of 6, 16.7%), thereby reducing the maximum number of skeletons in a data-set to 146.

These figures show that on balance the skeletal samples from church cemeteries are much smaller than those from monastic or hospital sites, with one exception. This is probably due to the fact that since many Medieval church cemeteries continue in use today they are consequently not threatened by development, providing less opportunity for archaeological investigation (Daniell and Thompson, 1999), whereas the monastic and hospital sites were all suppressed during the Dissolution, or shortly afterwards. There may be more public opposition to excavations taking place within the graveyards of parish churches compared to the excavation of a long-forgotten cemetery. This has implications for the skeletal sample available, as the general population buried within parish churchyards is not as well represented as the individuals following the regulated lifestyle of the religious, those experiencing the more privileged life of the wealthy, or the poor and sick who sought care in a hospital.

7.7.1.1 Proportions of Adults and Subadults.

The church and cathedral samples both had a proportion of adults and subadults close to 70:30, which were the proportions found in the majority of the preceding periods. This would be consistent with the burial of a cross-section of the population in the parish churches, or in the cathedral site. In contrast, both monastic and hospital samples had a low proportion of subadults, between 20-25%, and a high proportion of adults (75-80%), especially the hospital group. This might well reflect the nature of these institutions, with subadults tending to be excluded from burial in these cemeteries. Although religious houses originally took in oblates at a young age, by the end of the twelfth century the minimum age for admission to most religious orders was seventeen to nineteen years and most recruits entered in their late teens or early twenties (Burton, 1994; Knowles, 1961). As the burial grounds of religious houses tended to be used for the burial of the religious community and of high status individuals, this could have resulted in fewer children being present in the cemeteries. Hospitals had an even smaller percentage of children in the sample, possibly reflecting the provision of care mainly for adults. Indeed many hospitals provided care for specific groups of people, such as the elderly or those suffering from leprosy, and if this was the case then children are likely to have been excluded (Gilchrist, 1995). As with the religious sites, hospital cemeteries also acted as burial grounds for benefactors and the staff. Of course, the under-representation of children could simply reflect biases in excavation, but since there are a large number of monastic sites it becomes less likely that each excavation retrieved a sample biased in exactly the same way. With only three hospital sites it is less certain that excavation bias is not operating, but all three show the same trend.

7.7.1.2 Sex Distribution.

Both hospital and monastic cemetery samples had a high proportion of males, which is not unexpected. Monastic cemeteries included burials of the religious themselves, as well as high status individuals. Since all the monastic sites considered here were male houses, the preponderance of males is to be expected. Not all males were monks, friars or canons, as several would have been high status benefactors, and the presence of servants, pilgrims, and corrodians must also be considered likely. However, the possibility that more males are found in monastic samples because that is what the osteologist is expecting to find should also be acknowledged; at a subconscious level there may be a slight tendency to assign skeletons of indeterminate sex to the 'male' group to conform to the presumed sex distribution. The two hospital sites that provided data on caries prevalence in male and female teeth were Chichester and Spitalfields Market. The hospital of St. James and St. Mary Magdalene, Chichester, was founded specifically for the care of brethren with leprosy, and women were not admitted until c. 1540 (Magilton and Lee, 1989). It is not surprising to find that the skeletons from Chichester are predominantly male. In contrast, according to documentary evidence St. Mary Spital, London (Spitalfields Market), took in a wide range of people including the poor and sick, but seems to have been known for its care of pregnant women and their children and also for housing widows and orphans. Wealthy couples, corrodians, pilgrims, servants, lay brothers and sisters, and the canons themselves would also have resided at the hospital (Thomas, *et al.*, 1997). The sample from Spitalfields reflects this broader intake, with a more even distribution between the two sexes although males are still greater in number. However, since Chichester provided the larger sample, the overall hospital sample contains a higher proportion of males than females. The data from St. Leonard's Hospital were not included, as this site did not provide data on caries prevalence in male and female teeth, but as a comparison the sex distribution in this sample more closely matches that of Chichester, with 85.7% (66 of 87) of the skeletons being male. In this case the hospital appears to have accommodated the poor and infirm, although it was possibly originally intended for the care of people suffering from leprosy (Bishop, 1983). Although the sex of the inmates does not appear to be specified, the osteological evidence would suggest that males were the primary beneficiaries.

The proportions of males and females in the church cemeteries were not significantly different from a normal distribution, which is as expected if a cross-section of the population is being buried in them. However, if more males are buried in hospital and monastic cemeteries then it might be reasonable to suggest that a higher proportion of females should be found in the church cemeteries. Indeed a slightly higher proportion of females was observed (53.7%), although this was not nearly as great as the proportion of males found in the monastic (66.2%) or hospital (60.6%) samples. The potential biases in preservation that might result in female skeletons being less well preserved and so unable to be sexed have been highlighted by Walker (1995). He also observed that older females are more likely to be sexed as male, although the opposite situation arises with younger males, which are more likely to be sexed as female. Daniell (1997) has considered this problem, and does not believe that preservation bias or errors in sexing are enough to explain the missing females, and neither does he consider burial of females in nunneries to account for the difference, although few nunneries have been excavated to substantiate this idea. He suggests that infanticide of girls may have been practiced. Since subadult skeletons are virtually impossible to sex without the application of expensive DNA analysis it is difficult to be certain whether more girls than boys were dying in childhood, and although females dying before they reached maturity could be a reason for an under-representation of adult females, this would not necessarily have to be the result of infanticide. It could equally well be the result of poorer diet leading to under nutrition and greater risk of succumbing to disease, which might result if female children were less valued than male children.

7.7.1.3 Age Distribution.

7.7.1.3.1 Adults in General.

The age distributions of the church and monastic samples were not significantly different from each other. The majority of individuals in both groups were found in the two middle-adult categories, with a small proportion in the Young Adult group. Overall, the church sample had a slightly higher proportion of adults in the two older age groups combined than did the monastic sample. Assuming that the burials from the monastic cemeteries represent the inhabitants of the religious houses and the wealthier members of society, these age distributions imply that they were not tending to live longer than the general population buried in the church cemeteries. However, the accuracy of data on age is particularly suspect, and should be regarded with extreme caution.

The cathedral and hospital cemeteries showed age distributions that were significantly different from those of the other cemetery types. Three-quarters of the cathedral sample were distributed in the two middle-aged categories. Since the cathedral sample is made up of only one site it is possible that the osteologist was biased towards placing individuals in the two middle-aged categories. The hospital sample has the opposite trend to the cathedral sample, with the majority of the individuals found in the Young Adult and Old Adult age groups.

7.7.1.3.2 Adults: Male and Female Subdivisions.

The age distributions of the sexes were not found to be significantly different within each cemetery type. A high proportion of both males and females were found in the two older age categories in the church sample, although males did have a slightly higher proportion than females in this group. Likewise, a similar trend was noted for the monastic sample, with a slightly higher proportion of males being found in the older age groups than females. The opposite pattern was noted for the hospital sample, with a slightly greater proportion of females placed in the two older age groups.

7.7.1.4 Caries Prevalence.

7.7.1.4.1 Teeth From Adults.

Despite the fact that the church sample had the highest proportion of individuals in the two older age groups, it had the lowest caries prevalence (6.2%), and this prevalence rate was significantly different from that of all other groups. Two of the data-sets, both from the same site (Rivenhall), had particularly high caries prevalence rates, especially Rivenhall C (24.2%; see Appendix 6) and, as for Trowbridge, questions can be raised about the likelihood of such a high caries prevalence being found in a rural settlement in a period before refined sugar was widely available. Without the Rivenhall data the caries prevalence for the church sample is slightly lower at 5.7%, but both prevalence rates are low in comparison to the other samples. If the individuals in this sample do represent the general population, as the demographic profile seems to suggest, then this indicates that their diet was less cariogenic than that of the individuals buried in the monastic, hospital and cathedral samples. This lower prevalence rate would be consistent with a more restricted access to luxury (and cariogenic) foods such as sugar, quantities of honey, dried fruits, pastries and other sticky foods made from refined carbohydrates and sweetened, as well as the consumption of less-refined carbohydrates such as coarse bread (Dyer, 1989, 1998, 2000). It could also imply a higher consumption of cariostatic foods such as cheese and milk, which would again be consistent with documentary sources (Dyer, 1989, 1998, 2000), and perhaps some consumption of sea foods. Dried cod and salted herring (both marine fish) were among the cheaper fish products available: "stockfish [usually cod] was the standard poor man's fare of the Middle Ages" (Bond, 1988: p73). Dyer (1988) noted that expensive freshwater fish was served to the wealthier individuals at the high table, whilst the less important people and servants ate preserved herring and cod. Fresh meat and fish would be less likely to feature in the diet on a regular basis. As a comparison, an examination of skeletons excavated from a Quaker burial ground in Kingston-upon-Thames (AD 1664-1814) found this group to have a low caries prevalence of 5.4% despite the late date of the site, which was related to their simple lifestyle and diet (Start and Kirk, 1998).

The monastic sample had a caries prevalence (7.8%) that was significantly higher than that of the church sample, suggesting consumption of a more cariogenic diet. The problem is, who is present in the monastic sample? The religious themselves would have been buried in the monastic cemeteries, but the founders, benefactors and patrons of the religious houses would also have expected to be buried there (Brooke, 2003; Burton, 1994; Daniell, 1997). As time progressed, a wider section of society was able to endow religious houses and burial of the lay community expanded (Burton, 1994). Different areas of the site might be used for burial of different categories of people, for example the burial of monks and canons in a separate cemetery (often at the east end of the church), or the burial of abbots in the chapter house; however the chapter house could also be used for the burial of laity under some circumstances (Daniell, 1997). Depending on the area excavated a different group of individuals might be part of the sample, but it would be impossible to state categorically that all individuals excavated from 'x' location will be canons (for example) as variation in actual burial practice occurred between sites and through time. The problem with the data-sets included here is that a single figure is provided for the whole skeletal sample and there is no differentiation between those that might have been laity and those that were probably the religious. Since the monastic sample consisted predominantly of male individuals it seems likely that a proportion of them were monks, friars or canons (many of which are likely to have come from reasonably wealthy backgrounds (Burton, 1994)), although some will be benefactors or other individuals. Females buried within the cemetery of a male religious house cannot have been members of the community, and are therefore likely to represent high status individuals.

This mixture of categories of individuals complicates interpretation of the data on caries prevalence in the monastic sample. The wealthy individuals interred in the monastic sites would have enjoyed a more varied and lavish diet than that of the general population; the religious supposedly adhered to a strict Rule governing every aspect of daily life, including the food consumed. The Rule followed varied, with most of the orders in this sample following variations of the Rule of St. Augustine, which was open to reinterpretation and amendment to suit the requirements of each particular religious order (Brooke, 2003; Burton, 1994; La Corte and McMillan, 2004). However, the degree to which the dietary restrictions were observed has been the subject of much study, and both documentary and archaeological sources suggest that during the Late Medieval period the rules on food consumption were relaxed or largely avoided (Brooke, 2003; Burton, 1994; Harvey, B., 1993; Rogers and Waldron, 2001). Although this no doubt varied between different orders, and specific houses within each order, the diet came to resemble that of the wealthy. Both would have contained plentiful helpings of a variety of foods, including large quantities of meat and fish. Originally meat consumption was forbidden to monks, friars and canons, with large quantities of fish eaten instead, but during the Late Medieval period the strictures against meat consumption were evaded and meat became a regular feature of the monastic diet (Harvey, B., 1993; Burton, 1994; Brooke, 2003). Even so, the weekly and seasonal fast days and periods ensured that fish remained a substantial part of the diet, and it appears that most of the fish consumed were of marine origin (Bond, 1988, 2004). The upper classes also consumed a large quantity of fish as a result of the fast days imposed by the church, and again a large proportion of these were sea fish, although freshwater fish may have been a high status food (Dyer, 1988, 2000; Cosman, 1976). These large quantities of marine fish are likely to have exerted a protective effect against dental caries, and the meat and freshwater fish consumed would also not have placed teeth at risk; the likelihood that fish were a more prominent part of the religious diet could mean that they enjoyed greater protection from caries. Dairy produce, especially cheese, may have been consumed in larger quantity in the religious houses than by the wealthy, who possibly associated 'white meats' with the poor (Harvey, B., 1993; Dyer, 1989). In this respect the religious may again have experienced greater protection from dental caries. However, the diet of the wealthy and religious probably contained many more cariogenic factors than that of the general population. Bread would have been made from finely ground flour, and perhaps enriched with the addition of spices, dried fruits or honey (McKendry, 1973;

Hagen, 1992). Both practices would have increased the cariogenicity of the food, although the bread consumed by the religious may have been coarser than that habitually eaten by the upper classes (Black, 1992). Dried or candied fruits, honey, sweetmeats, pastries and sugar were all affordable and available in larger quantities, although the wealthy probably consumed these items more often.

Therefore, the diet of the wealthy contained many more cariogenic items than that of the general and, to some extent, the monastic populations, which are likely to have placed their teeth at greater risk, although the large quantities of marine fish consumed may have lessened the danger. The religious communities were also likely to have consumed more cariogenic items than the general population, but perhaps not as much as did the wealthy. However, this will have been influenced by how strictly the Rule was being observed in each house. They also ate quantities of sea fish, and probably more cheese, both factors that would have helped protect their teeth. If meals were restricted to the regulated one or two per day (according to season and fast days) then this would have been an additional factor that would have reduced the risk of caries development. However, there are indications that more frequent food consumption may have occurred; for example, the canons of Newburgh were "ordered not to wander round the cloister after compline in search of food and drink, either to consume alone or with guests" following a visitation by Archbishop Wickwane of York (Burton, 1994: p185).

The caries prevalence observed in the monastic sample would be consistent with a more cariogenic diet than that of the general population. To what extent this reflects the diet of the wealthy individuals present in the sample, and how much can be attributed to the diet of the religious, is unknown. An investigation of the sex differences present in the sample might help elucidate the situation, and this is discussed below.

The cathedral cemetery (Whithorn B) resembled the church cemetery sample in terms of demographic structure: the proportion of adults to subadults in both was close to 70:30, and the proportion of males and females were almost identical (Cathedral: M = 46.9%, F = 53.1%; Church: M = 46.3%, F = 53.7%). However, the age distributions were significantly different, with the church sample having a higher proportion of older individuals whereas most of the individuals were found in the two middle-aged adult categories in the cathedral. However, in terms of caries prevalence the cathedral sample was closest to the monastic sample, with a caries prevalence of 7.9%. This indicates that the individuals buried at the cathedral cemetery probably consumed a more cariogenic diet than the general population buried in the church cemeteries. This might indicate burial of a higher status group of individuals at Whithorn B, which was an important centre for pilgrimage (Hill, 1997), but another possibility might relate to the urban or rural location of the church, monastic and cathedral cemeteries. All monastic sites were located in or on the borders of towns or larger urban areas, whereas most of the church data-sets came from rural areas and only two came from towns. In developing countries, caries prevalence has been observed to rise in urban areas first, due to an increased availability of sugars and other cariogenic foods and changes in traditional consumption patterns in towns (Okullo, *et al.*, 2003; Åstrøm and Haugejorden, 2000; Ettinger, 1999; Enwonwu, 1974; Meyer-Lueckel, *et al.*, 2002). The fact that both monastic and cathedral samples have a similar caries prevalence might reflect the urban location of these sites, whereas the church sample might reflect the predominantly rural location. Examination of the caries prevalence for individual sites does not appear to support this hypothesis, as several of the rural sites have the highest caries prevalence. However, the Isle of Ensay and Chevington Chapel rural populations may date slightly later than most others (see Figure 5.5:2), which may have meant these populations had increased access to cariogenic foodstuffs such as sugar as it declined in price, and the reliability of the Rivenhall data has been questioned above. One of the two urban sites was St. Helen-on-the-Walls, known to have been the church of one of the poorest parishes in York (Dawes and Magilton, 1980; Magilton, 1980), and the low caries prevalence of this sample (4.4%) no doubt reflects this.

The caries prevalence of the hospital sample was the highest (12.8%) and significantly different from the other cemetery types. Although this sample did include a large proportion of Old Adults, a similar proportion was found in the Young Adult group. This sample might be expected to show a similar prevalence rate to the monastic sample, since both hospitals and religious houses were organised in a similar manner and the hospital was staffed by members of a religious order living according to a Rule (Gilchrist, 1995; Burton, 1994). Like religious houses, burials in the hospital cemetery would have been accorded to the benefactors and patrons of the hospital, so inclusion of some high status individuals in the sample might be expected. However, the cemetery would also have included burial of the inmates, who were likely poor, sick, elderly or infirm, as well as any corrodians in residence (Gilchrist, 1995; Thomas, *et al.*, 1997).

Although the food fed to the inmates of the hospital was likely to have been different to what they might have consumed outside the hospital, it was unlikely to have been any more cariogenic than that served in other religious institutions. It probably consisted of cereal staples, in the form of bread, pottage and ale, pulses and legumes, meat and fish (both freshwater and marine), and some vegetables and fruit (Thomas, *et al.*, 1997; Price and Ponsford, 1998; Talbot, 1967; Gilchrist, 1995). It is unclear how much fruit and vegetables would have been eaten, as these seem to have been regarded as unhealthy by medical opinion of the time; fruit was probably cooked or preserved rather than eaten fresh (Thomas, *et al.*, 1997). This processing could have rendered fruit more cariogenic, but similar methods of preparation were no doubt followed in other locations. Dried fruits also seem to have been available to the residents in hospitals (Thomas, *et al.*, 1997), another potential cariogen.

One possible explanation for the high caries prevalence observed is that the poor people present in the sample had suffered from malnutrition, which may have placed them at increased risk of developing caries through the poor development of tooth enamel and lower salivary flow rates often observed in undernourished individuals (Moynihan, 2003). Lewis (2002) found a correlation between enamel hypoplasia (indicative of undernutrition) and dental caries in her study of subadults in Medieval Britain. Another possibility is that sick individuals may experience changes in oral physiology, which might have predisposed to the development of caries, but such conditions would have to persist for a time before death for carious lesions to develop. The way in which food was prepared for consumption by the sick might have increased its cariogenicity, for example, carbohydrate foods boiled and mashed to a pulp, perhaps sweetened with a little honey or boiled fruits (O'Sullivan, *et al.*, 1993; Lee, 2001). Honey featured prominently in medical remedies, and sugar appears have been viewed as having medicinal qualities (Brothwell and Brothwell, 1998; Black, 1992; Gilchrist, 1995; Cameron, 1993), although the extent of medical treatment provided at hospitals was probably minimal (Gilchrist, 1995).

7.7.1.4.2 Teeth from Adult Male and Female Subdivisions.

In contrast to the data for adult teeth, the data for male and female teeth show a different trend. In the church sample both male and female teeth have higher caries prevalence than the monastic sample, with the male prevalence being higher than the male hospital sample. This might be explained by the general lack of reporting of caries prevalence in male and female teeth for the church data-sets, resulting in a smaller sample size: of the seven data-sets that provided data on teeth from adults, only four provided data on male and female teeth, and two of these (Rivenhall C and D) were for the same site. Rivenhall C and D both had the highest caries prevalence rates, and that for the Rivenhall C males was particularly high (see Appendix 10). Without the data for Rivenhall the caries prevalence rates are lower (M = 8.6%, F = 10.7%), but still high in comparison with the data for adult teeth as a whole and the monastic sample. However, this difference between church and monastic caries prevalence was not significant for either sex. It seems as though the data for caries prevalence in male and female teeth, in the church sample, has been affected by particularly small sample sizes and possibly unreliable recording of data. It is therefore difficult to draw any firm conclusions regarding differences in caries prevalence in the church sample: if the Rivenhall data is included then it is the males that have the higher caries prevalence, but if Rivenhall is excluded then the female prevalence rate is greater; in neither case is there a significant difference between the caries prevalence of males and females.

In contrast to the church sample, all ten monastic data-sets had provided data on caries prevalence in male and female teeth. This might reflect a greater interest in examining differences between the sexes in monastic contexts in order to investigate potential differences in diet between monastic and lay populations. If a proportion of the males in the monastic sample are monks, friars or canons, and they were adhering to the regulations governing food consumption, then it might be expected that the males in the sample would show a lower caries prevalence than the females, most of whom were probably high status and consuming a high status diet. Since no significant difference was found between the caries prevalence of male (7.8%) and female (8.6%) teeth in the monastic sample, this could imply that the religious were not adhering to dietary regulations and were consuming a cariogenic diet much like that of the wealthy. Alternatively, few of the religious are included and the samples mainly comprise wealthy individuals of both sexes. A problem when using the sex-differences in caries prevalence to investigate this question is the tendency for a higher prevalence rate to be found in female teeth. Without adequate data from the church sample, and with data completely lacking from the cathedral sample, there is no comparative material for the general population with which to establish what might be expected in terms of sex-differences in caries prevalence in the Late Medieval period.

Only the hospital sample had significantly different caries prevalence between male and female teeth, both of which were significantly higher than the monastic samples. Female teeth showed a higher caries prevalence (17.4%) than the male teeth (13.1%); although there were no significant differences in age distribution there were slightly fewer females in the Young Adult age groups compared to males. The high prevalence seen in both sexes might relate to the presence of undernourished poor individuals, or the feeding of soft processed carbohydrates to the sick. The latter food would require little chewing and so be unlikely to stimulate salivary flow. Mazengo *et al.* (1994) observed that salivary buffering was highest in individuals consuming a fibrous diet requiring vigorous chewing, but buffering was significantly lower in females consuming a less fibrous diet than it was in males; this trend was separate from trends in salivary flow rate. It is possible that when fed a soft, carbohydrate-rich diet that females become at greater risk of caries development than males. Another possibility is that the females suffered more generally from undernutrition than did the males, which might occur if preferential access to food was given to males (Hagen, 1992).

Although the original intention may have been that the food was shared equally between sisters and brethren in such institutions, it appears that there were cases where the funds were mismanaged at the expense of the women, such as the Gilbertine double-monasteries, where the canons soon kept "the women short of food while they had plenty" (Burton, 1994: p103); at Swine Priory, Yorkshire the nuns were living on bread, cheese and ale while "the resources intended for the nuns are being diverted for the benefit of the canons alone" (Golding, 1995: p134). Such practices occurred in hospitals, and one such incident was reported for St. Mary Spital, London (Spitalfields Market): a visitation by Bishop Baldock in the early fourteenth century found that "the sisters had had their pittances withheld from them for several years. [He] ordered this to be rectified and also that the sisters should be issued with the same food as the canons, and not with meals made up of leftovers" (Thomas, *et al.*, 1997: p43). It is likely that such practices affected the cariogenicity of the diet consumed by the lay sisters. As the canons would have kept any luxury foods to themselves, it is unlikely that the sisters would have eaten dried fruits, honey, sugary foods, or fine bread and so their diet may have been less cariogenic. Fish and meat may have been withheld as well, depriving them of any protective benefits of protein in the diet or fluoride from marine fish, although if cheese were allowed then this would be beneficial. Since the nature of the 'leftovers' is unknown, it is impossible to comment further. Although such an inadequate diet would seem unlikely to place the women at risk of caries, the danger of undernutrition would have been high, with the consequent risk of susceptibility to caries.

Alternatively, the high female caries prevalence might reflect a higher proportion of high status females in the female sample compared to the proportion of high status males in the male sample. This may have occurred at Chichester, where the initial phase of the hospital was for brethren suffering from leprosy, but at Spitalfields Market the inmates included pregnant women and widows, and the staff included lay sisters and servants.

7.8 Non-Monastic And Monastic Sites: Early, Middle and Late Medieval.

7.8.1 Non-Monastic Sites.

The majority of the Early and Middle Medieval data-sets come from non-monastic contexts, with the result that over 90% of the skeletons in both periods are found in these sites. This is in comparison with the Late Medieval church cemeteries, which contain only 27% of the total Late Medieval skeletons. The tendency for the skeletal samples from church cemeteries to be smaller than those from religious (monastic and hospital) sites has been discussed in Section 7.7.1 above. There is virtually no change from the total Early Medieval sample in terms of the mean number of skeletons per data-set (108.2), and the proportion of data-sets containing over a hundred skeletons (11 of 21, 52.4%) when the non-monastic sites are considered on their own (see Section 7.6.1). Likewise, the difference between the Middle Medieval non-monastic data-sets and the total Middle Medieval sample is also small: the mean number of skeletons in a non-monastic data-set is 165.4, and 62.5% (5 of 8) have more than a hundred skeletons (compare with Section 7.6.1). In contrast to the total Late Medieval sample, where an overall increase in the number of skeletons in total and per data-set is observed from the two earlier periods, the church sample has a lower number of skeletons than the preceding two periods, and the individual data-sets also tend to be smaller.

7.8.1.1 Proportions of Adults and Subadults.

As with the main periods in general, the Early and Late Medieval non-monastic sites both consist of close to 70% adults and 30% subadults, but the Middle Medieval period has a lower proportion of adults and a higher proportion of subadults. The former are consistent with a cross-section of the populations being buried in the cemeteries, but the latter remains difficult to interpret.

7.8.1.2 Sex Distribution.

Neither Early nor Late Medieval non-monastic samples differed significantly from an equal division of the sexes, although the Middle Medieval sample was significantly different at the 5% level. A normal sex distribution would be expected in cemeteries where a cross-section of the population had been buried, although the slightly higher proportion of males in the Middle Medieval sample is difficult to explain.

7.8.1.3 Age Distribution.

7.8.1.3.1 Adults in General.

In both earlier periods the non-monastic sample has a greater proportion of individuals in the two younger age groups, but the situation is reversed in the Late Medieval church sample. The age distribution for each period was significantly different from the other periods.

7.8.1.3.2 Adults: Male and Female Subdivisions.

No significant differences between the age distribution of males and females were noted within any of the three periods. However, for all three periods there was a tendency for a higher proportion of males than females to be placed in the two older age groups, and for a greater proportion of females to be found in the Young Adult age category (although this latter trend was not as pronounced in the Late Medieval sample).

7.8.1.4 Caries Prevalence.

7.8.1.4.1 Teeth From Adults.

A similar pattern was observed in the non-monastic samples as in the total samples for the Early, Middle and Late Medieval periods. Although the difference was not as pronounced, the caries prevalence in the Early Medieval period (5.1%) was significantly lower than that of the Late Medieval period (6.2%). This difference remains even if the data for Rivenhall are excluded from both data-sets, and although the difference between the two samples is even smaller, it is still significant at the 5% level (EM = 5.1%, LM = 5.7%). However, the Late Medieval sample does contain a larger proportion of adults in the two older age categories combined than are found in the preceding two periods and it is entirely possible that this higher caries prevalence may be attributed to this fact.

Without better data on caries in relation to the age distribution within each sample it is difficult to be sure that this apparent trend does exist. If it does, then the implication is that essentially the diet of the general population in both periods remained similar, with some changes towards a more cariogenic diet occurring in the Late Medieval sample. This could be a slight increase in the availability of sugar or other luxury items such as dried fruits, but on balance this seems unlikely. Alternatively, these changes may be linked to changes in food preparation, such as increased consumption of bread made from a more finely ground flour, or carbohydrates processed in such a way that they become sticky and adhere to the teeth. Other possibilities include a lower consumption of dairy produce, such as cheese, which may have occurred towards the end of the Late Medieval period as the poorer classes attempted to emulate the diets of the gentry (Dyer, 1998). Since the consumption of marine produce increased considerably in the Late Medieval period (see Section 7.10.1.4) it is possible that the consumption of more cariogenic foods was counterbalanced by the consumption of marine fish. However, better data are required to ascertain whether this trend really does exist.

Again, the Middle Medieval sample is dominated by Trowbridge, which, if these data are included, means there is a significant difference between the Middle Medieval sample (caries prevalence 9.4%) and both Early and Late Medieval samples. Without Trowbridge, the prevalence rate reduces to 5.9%, and if the Rivenhall data is excluded as well then the prevalence becomes 5.7%, neither of which is significantly different from the caries prevalence of the Late Medieval period, and both of which are significantly different from that of the Early Medieval period.

7.8.1.4.2 Teeth from Adult Male and Female Subdivisions.

No significant differences in caries prevalence between male and female teeth exist in any of the three periods, and neither were there significant differences in age distribution between the sexes. The Early and Middle Medieval samples both have low prevalence rates in both sexes, and the similarity in caries prevalence between the two sexes implies a similarity in diet in the general population. The dubious nature of the data for the Late Medieval church cemeteries has already been discussed (Section 7.7.1.4), which hinders any useful comparisons with the preceding two periods in terms of potential sex differences in diet.

7.8.2 Monastic Sites.

Whereas the monastic sites are well represented in the Late Medieval sample (see Section 7.7.1), they are less well represented in the Early and Middle Medieval periods, both in terms of number of skeletons and number of data-sets. The Middle Medieval monastic sample is represented by one site (Holy Trinity Priory, London), which happens to be amongst the smaller of the sites used in this study, numbering only 39 skeletons. This is lower than the average for both Early and Late Medieval monastic sites, and lower than the average non-monastic Middle Medieval data-set. However, the Early Medieval monastic data-sets have a slightly higher mean number of skeletons (111.5) than the non-monastic Early Medieval data-sets, and one of the two sites had over a hundred skeletons.

7.8.2.1 Proportions of Adults and Subadults.

The Late Medieval monastic sample has already been discussed (see Section 7.7.1.1), but in summary it was noted that there was a lower percentage of subadults present than might be expected if a cross-section of the population was represented in the sample (subadults = 24.7%, adults = 75.2%). The Middle Medieval monastic group consisted of only one site, so too much cannot be inferred from such a small sample. However, it is interesting to note that this data-set shows an even lower proportion of subadults (7.7%), with adults making up 92.3% of the sample. In temporal terms this skeletal population dates to a period when the acceptance of young boys into religious orders was discouraged and then regulated against, and when burial within religious cemeteries was restricted to the religious themselves and the founders, benefactors and patrons of their houses (Burton, 1994). Children may not regularly have been given burial in such a prestigious location in the eleventh and twelfth centuries. If Holy Trinity Priory is representative of other monastic cemeteries of the period, then it would seem as though the proportion of children buried in religious houses increased in the Late Medieval period as the privilege of burial within a religious cemetery was extended to larger sections of the population, although they still did not reach the same number as those buried in the church cemeteries. However, the low proportion of subadults at Holy Trinity Priory could simply be the result of biases in preservation or excavation.

In contrast, the Early Medieval sample had a high proportion of subadults (38.6%) and a lower proportion of adults (61.4%). Again, this group is represented by a small sample of only two sites in comparison to the ten sites of the Late Medieval period. One of these two sites (Whithorn A) shows a proportion of adults and subadults very similar to that for the Late Medieval monastic sites as a whole (75.5% and 24.5% respectively), whereas adults make up only 57.1%, and subadults 42.9%, of the sample from the other site (Jarrow A). Perhaps the large percentage of subadults in this data-set represents the presence of young oblates before this practice was discouraged (Burton, 1994), but this same site has similar proportions of adults and subadults in the Late Medieval phase (see Section 7.8.2.1). Alternatively it could be the result of accidents of preservation and excavation. In general it seems as though monastic sites are characterised by a lower proportion of subadults than would be found in a church cemetery or an earlier non-monastic site, but this is obviously not always the case.

7.8.2.2 Sex Distribution.

The sex distribution of the Late Medieval monastic sites has been discussed in Section 7.7.1.2. In summary, the monastic sample contained a high proportion of males (66.2%) as might be expected. In comparison, the only Early Medieval monastic site (Jarrow A) to provide data on caries prevalence in male and female teeth contained a lower proportion of males than this (56.2%) which, although males still outnumbered females, was not significantly different from a normal distribution. This same site also contained a higher than usual proportion of subadults in both Early and Late Medieval phases. With just one site it is difficult to know how representative it is of other monastic sites of the period. In view of this, the proportion of males and females in the Early Medieval phase of Whithorn (A) are discussed as a comparison, although this site was not included in the figures since it does not provide data for male and female teeth. At Whithorn A the proportion of males (66.7%, 14 of 21) was similar to that observed in the Late Medieval monastic sample, and the proportion of subadults at this site was also found to be similar to that in the Late Medieval monastic sample (see above). Either Jarrow A is unusual in having a higher proportion of females and subadults than other monastic sites of the period or of later date, or the excavation has retrieved a biased sample of individuals.

7.8.2.3 Age Distribution.

7.8.2.3.1 Adults in General.

The Early Medieval monastic sample showed a large proportion of adults in the two older age groups (62.0%), which was much higher than the 46.4% of the adults from the non-monastic sites. In addition, only 12.7% of the monastic samples were placed in the Young Adult group compared to 26.4% of the non-monastic sample. These figures could indicate that living conditions were favourable for the inmates of religious houses in comparison to those of the general population in the Early Medieval period, although the sample size available for the monastic group is small. In contrast, the opposite trend is observed in the Middle Medieval sample, where 70.8% of the adults in the monastic group are placed in the two younger age groups compared to 54.8% in the non-monastic sample, but again the comparison suffers from the small sample sizes available. The Late Medieval monastic and church samples have been compared in Section 7.7.1.3, but in summary no significant differences were noted between the two. The only significant difference found between the age distributions of the monastic samples from the three periods was between those of the Early and Middle Medieval samples.

7.8.2.3.2 Adults: Male and Female Subdivisions.

There were no data available for caries prevalence in male and female teeth in the Middle Medieval period. For neither Early nor Late Medieval periods were there significant differences in age distribution between males and females.

7.8.2.4 Caries Prevalence.

7.8.2.4.1 Teeth From Adults.

The caries prevalence rates in both Early (3.4%) and Middle Medieval (3.0%) monastic samples were low, and were not significantly different from each other. Both were significantly lower than the non-monastic sample of the same period (EM = 5.1%, MM = 5.7% (Trowbridge and Rivenhall excluded)). This trend is observed despite the fact that the Early Medieval monastic sample had a higher proportion of older adults than the non-monastic sample. However, since the Middle Medieval monastic sample had more younger adults than the non-monastic sample a lower caries prevalence might be expected. These data imply that the diet consumed in early monasteries was even less cariogenic than that of the general population of the time, which suggests that the strict dietary regulations of early monastic life were adhered to.

Early monasteries did not follow a coherent and unified Rule, as each adapted the customs of other monasteries for their own use; for example Benedict Biscop "the founder of Wearmouth/Jarrow, declared, according to Bede's well known account, that he had derived his "Rule" from the best employed in seventeen monasteries in England and the Continent" (Cramp, 1999: p137). The Rule of St. Benedict, written c. AD 535-545 and which came to dominate Western monasticism, was only one of many Rules available and "it is more appropriate, therefore, to think of religious houses in early Anglo-Saxon England following a pattern of existence shaped both by Benedict's rule and by local customs" (Burton, 1994: p1). Benedictine Rule forbade the consumption of quadrupeds, "except for the sick who are really weak" (Parry and de Waal, 1990: p67), and recommended a plain and austere diet as "there must be no danger of over-eating, so that no monk is overtaken by indigestion, for there is nothing so opposed to Christian life as over-eating" (Parry and de Waal, 1990: p67). Two meals a day were to be had in summer, a main meal in the middle of the day and a light supper in the early evening, with one meal in the early afternoon in winter. The daily 'measure of food' consisted of two cooked dishes at the main meal, which were intended to provide a choice rather than be complementary, supplemented by a third of fruit and vegetables if these were available. This was accompanied by a pound of bread, but a third of this was kept back for supper if two meals were to be consumed that day (Parry and de Waal, 1990; Fry, 1981; La Corte and McMillan, 2004; Burton, 1994). Since meat was forbidden it is likely that fish was consumed instead, and bones of marine fish have been found at Jarrow and other Early Medieval monastic sites (Huntley and Stallibrass, 1995). Ale is likely to have been the main drink, but wine might be allowed in moderation "for although we read that wine is not at all a drink for monks, yet, since in our days it is impossible to persuade monks of this, let us agree at least about this that we should not drink our fill, but more sparingly" (Parry and de Waal, 1990: p68). Such a diet, consisting of coarse bread, cereals and fish, with some vegetables and fruit, consumed infrequently at defined times would have very little cariogenic potential. Not only was the food largely non-cariogenic, but also the restriction to one or two meals a day would have limited the periods of demineralisation of tooth enamel associated with food consumption. However, sugar was reportedly among the spices left to the brethren by Bede following his death (Hagen, 1995), and although this quantity was no doubt small and perhaps used for medicinal purposes, this does illustrate that some cariogenic foods might have been available.

The Middle Medieval sample, consisting of Holy Trinity Priory, London, also shows a low caries prevalence. Since this was one of the first houses for Augustinian canons to be founded in Britain (Aston, 2000) it is likely that there was enthusiasm for adherence to the Augustinian Rule. Although the Rule of St. Augustine originated around AD 400, it did not become a feature of monastic life until it was adopted by the canonical orders in the eleventh century (Burton, 1994; La Corte and McMillan, 2004). It was possible to adapt the Rule for local requirements, and so it is difficult to be certain of the exact dietary strictures. However, the Rule recommended "fasting and abstinence from food and drink" and if unable to fast "he should still take no food outside mealtimes unless he is ill" (La Corte and McMillan, 2004: p55; Lawless, 1987). It appears as though a more lenient diet might be allowed those of delicate health, and that the sick were given "the kind of treatment that will quickly restore their strength… Once in good health, they must not become enslaved to the enjoyment of food which was necessary to sustain them in their illness" (La Corte and McMillan, 2004: p56; Lawless, 1987).

In contrast, the Late Medieval sample has significantly higher caries prevalence than both the preceding periods and the Late Medieval church sample. This could reflect the burial of wealthy individuals, who would have been consuming a more cariogenic diet, in the religious houses; it could also indicate a relaxation of the dietary prohibitions (see Section 7.7.1.4). However, many of the sites included in this study are those of the Mendicant orders which were established in Britain during the early thirteenth century (Burton, 1994). These orders were founded in an attempt to return to the rigours of original religious life through embracing absolute poverty, whilst educating the general population through "teaching and preaching by word and example" (Burton, 1994: p109). Many of these orders were based on the Augustinian Rule, but this was often reinterpreted and unfortunately less is known of the details relating to diet (Knowles, 1962; Burton, 1994; La Corte and McMillan, 2004). It is likely that, as with preceding monastic orders, the initial phase of Mendicant activity was characterised by strict observance of dietary regulations, but that as the initial fervour wore off the Rule became more relaxed and the food consumed more luxurious. Burton (1994: p129) has suggested that "by about 1260 the era of simplicity was over". The problems of interpreting the data for the Late Medieval monastic sample have already been discussed (Section 7.7.1.4), and in an attempt to investigate any differences further the different religious orders will be examined separately in Section 7.9.

7.8.2.4.2 Teeth from Adult Male and Female Subdivisions.

The caries prevalence in male and female teeth shows the same pattern as for the adult teeth (although there are no data available for the Middle Medieval period). Both male (1.1%) and female (0.8%) caries prevalence in the Early Medieval sample is exceptionally low, and significantly lower than that of the non-monastic males and females of the period. There is no significant difference between the sexes in terms of caries prevalence or age distribution, suggesting a similar diet was consumed by both sexes. A low male caries prevalence might be expected, if the males in the sample represent the burials of monks, but the reason for the low female prevalence is less clear and remains unexplained at present. These data are based on only one site (Jarrow A), and how representative it is of other monastic communities of the period and in different regions is unknown. The high proportion of subadults and females in comparison to other religious cemeteries suggests that it may not be. The data for the Late Medieval monastic sample have already been discussed in Section 7.7.1.4.

7.9 Late Medieval Sites: Monastic Orders.

The Late Medieval monastic sites as a whole have been discussed in Section 7.7.1, where it was noted that the sample had a higher mean number of skeletons per data-set than the church cemetery sample, and also a substantial proportion (80.0%) of data-sets numbering over a hundred skeletons. The best represented of the religious orders was the Dominican order, both in terms of the number of skeletons (642 of 1689, 38.0%) and number of sites (4 of 10, 40%). They averaged 160.5 skeletons per data-set, with the maximum number of skeletons being 250, and three of the four data-sets had over a hundred skeletons (75.0%). The Carmelites were the only other order to be represented by more than one site, making up 30% (3 of 10) of the monastic data-sets, but they only contributed 20.2% of the skeletons (342 of 1689). They also had the lowest mean number of skeletons per data-set (114.0), and two of the three sites (66.7%) had more than a hundred skeletons. The remaining three orders were each represented by one site, each with over a hundred skeletons. The Benedictine group contributed the smallest number of skeletons overall, but the proportion (11.2%) was in line with the proportion of sites (10.0%). However, the Augustinian and Gilbertine data-sets both contributed more than their share of skeletons (14.5% and 16.0% respectively).

Although it is difficult to draw conclusions when several groups are represented by only one site, it seems as though each of the religious orders have provided a respectable skeletal sample. The Benedictine group is least well represented, but the Carmelite data-sets showed a trend towards being smaller than those of the other groups.

7.9.1.1 Proportions of Adults and Subadults.

When the proportion of adults and subadults within the sample for each order is examined two groups emerge. In the first, consisting of the Augustinian, Dominican and Gilbertine samples, adults make up over 80% of the sample, and the subadults between 10-20%. These proportions are much closer to those observed in the skeletons from Holy Trinity Priory (the single Middle Medieval monastic data-set), and are markedly different from the 70:30 ratio that appears to be normal for church cemeteries. The second group consists of the Benedictine and Carmelite samples, and these again diverge from the 70:30 ratio but in the opposite direction. Sixty percent of the skeletons from the Benedictine site (Jarrow B) consisted of adults, and close to 40% were subadults. This is close to the proportions of adults and subadults observed in the Early Medieval phase of this site. The divergence is even greater in the Carmelite group, where only 52.6% of the skeletons in the sample were adults and 47.4% were subadults even though one of the sites (Perth) contained no subadults at all. At all three Carmelite sites the possibility that lay burial continued after the Dissolution is considered likely (Stones, 1989a), and this may partly account for the large proportion of subadults. Likewise Jarrow continued in use as a church following the Dissolution (Cramp, 1969), and the possibility that some post-Dissolution burials may have been included in the skeletal sample must be considered. However, this is unlikely to account for the high proportion of subadults seen in the earlier phase of the site.

In general it seems as though the samples for the Augustinian, Dominican and Gilbertine groups fit the pattern expected for a religious cemetery, with a larger proportion of adults. This suggests that these samples are likely to fit the assumption that they consist of members of the religious community and high status individuals. Conversely the rather large proportion of subadults in the Benedictine and Carmelite groups raises the possibility that a broader section of the population is represented.

7.9.1.2 Sex Distribution.

The same two groups observed, when proportions of adults and subadults were discussed (see above), re-emerge when sex distribution is considered. The Augustinian, Dominican and Gilbertine groups all have significantly more males than females in their samples, with males making up between 66-76% of the sexed adults. In contrast, the sex distributions of neither the Benedictine nor Carmelite groups differ significantly from normal, and whilst they did not differ significantly from each other they were significantly different from the other three groups. As with the proportion of adults and subadults, the Benedictine site (Jarrow B) had an almost identical sex distribution in the Late Medieval phase (M = 56.0%, F = 44.0%) as it did in the Early Medieval phase (M = 56.2%, F = 43.8%). Again, the Carmelites show the most extreme difference, with exactly half of the sample being males and half females. These figures tend to reinforce the conclusion drawn above, that the Augustinian, Dominican and Gilbertine samples are more typical of what one might expect for a monastic sample (mainly adults, of which most are males) whilst the Benedictine and Carmelite samples appear to include a broader spectrum of individuals (a large proportion of subadults and a high percentage of females amongst the adults).

7.9.1.3 Age Distribution.

7.9.1.3.1 Adults in General.

Again the Augustinian, Dominican and Gilbertine samples were not significantly different from each other in terms of age distribution. All three contained more individuals in the two older age groups and a tendency towards a low proportion of adults in the Young Adult category, although this pattern was most marked in the Augustinian sample. The Benedictine sample had the highest proportion of individuals in the Old Adult category, and a substantial proportion in the two older age groups combined. The Benedictine sample was not significantly different from the Dominican sample, but was different from all others. As with the proportion of adults and subadults, males and females, the Carmelite group emerged as being significantly different in character from the other groups, this time also being different from the Benedictine sample. The Carmelite sample was the only group to have a high proportion of adults in the two younger age groups, and it had the lowest percentage of individuals in the Old Adult group. Again, the evidence of the Carmelite age distribution continues to contradict the expectation of what a sample from a religious cemetery should be like.

7.9.1.3.2 Adults: Male and Female Subdivisions.

In three of the samples (Augustinian, Benedictine, and Carmelite) a higher percentage of males were found in the two older age groups. This tendency was particularly prominent in the Carmelite sample, where the proportion of males was double that of females in these groups combined, but even so the proportion of males in these groups was still below half. In the remaining two samples (Gilbertine and Dominican) proportionally more females than males were located in the older age groups. However, these differences between the sexes were not found to be significantly different for any of the samples.

7.9.1.4 Caries Prevalence.

7.9.1.4.1 Teeth From Adults.

Again, the same sites emerge as different in terms of caries prevalence: the Carmelite and Benedictine groups both had the lowest caries prevalence (C = 4.1%, B = 4.4%), and although not significantly different from each other, they were significantly different from the other samples. This low caries prevalence in the Carmelite sample might be accounted for to some extent by the high proportion of younger adults, but the Benedictine sample contained the highest proportion of Old Adults of any of the monastic groups, which makes such a low caries prevalence particularly notable. In most respects these two samples were similar since both had a high proportion of subadults and females. However, a high proportion of the females in the Carmelite sample were young, whilst the Benedictine sample had a high proportion of older individuals of both sexes. Is the low caries prevalence observed related to the difference in demographic structure between the Benedictine/Carmelite samples and the Augustinian/Dominican/Gilbertine samples? This is a possibility, as the high proportion of females and subadults in the Benedictine and Carmelite samples suggests that both skeletal samples contain a large proportion of the lay population, although the differences in age distribution indicate that exactly the same groups may not be represented in both samples. The low caries prevalence (even lower than that of the church samples of the period: 5.7% without Rivenhall) implies that these might be burials of the general population rather than high status individuals in particular.

On the other hand, if these groups do contain members of the religious community then the caries data suggest that they were adhering to the dietary regulations of their respective Rules in this late period. The Benedictine monks are generally believed to have abandoned their Rule during the course of the Late Medieval period (Harvey, B., 1993; Rogers and Waldron, 2001), indulging in rich and varied diets that would have contained more in the way of cariogenic foods, although the large quantities of marine fish consumed might have acted as a protective measure. If these skeletons include monks, then these data might suggest that the monks at Jarrow were continuing to observe dietary regulations. The Carmelite order originally observed a "strict and eremitical" Rule, but this was revised c. AD 1250, and modelled closely on that of the Dominicans who followed a version of the Rule of St. Augustine (Knowles, 1962: p197; Burton, 1994).

The Augustinian, Dominican and Gilbertine groups were similar in many ways. Each had a high proportion of adults in comparison to subadults, a large proportion of males and more individuals in the older age groups than in the younger. This demographic structure would be consistent with the burial of members of the religious community, plus some lay burial. However, although the Augustinian and Dominican samples had a similar caries prevalence (A = 7.3%, D = 8.1%), the Gilbertine caries prevalence was significantly higher (12.1%). Each of these religious orders followed a variation of the Augustinian Rule, with that of the Augustinian Friars being modelled on that of the Dominican Friars (Burton, 1994; Golding, 1995; La Corte and McMillan, 2004). Both Augustinian and Dominican were Mendicant orders, whereas the Gilbertine order incorporated canons. The Gilbertine order had a complex structure and was originally founded to provide a vocation for women desiring to follow a strict religious life (Golding, 1995). Lay sisters and then lay brethren were added, each following a version of the Rule of St. Benedict inspired by the strict Cistercian interpretation. At a later date Augustinian canons were introduced to take care of the order, but soon the canons assumed greater importance, and many male-only houses were formed. The house at St. Andrew Fishergate, York, was one of these and Golding (1995) suggests that these male houses must have been largely indistinguishable from those of Augustinian canons. Since the Augustinian Rule was flexible and easily adapted, little is known of the dietary restrictions that were in place in these orders (Brooke, 2003).

The higher caries prevalence seen in the Augustinian, Dominican and Gilbertine samples suggests that the individuals in the sample were consuming a more cariogenic diet than both the general population and the individuals in the Benedictine and Carmelite samples. If a large proportion of these individuals are friars or canons, then this could imply that adherence to dietary regulations had lapsed. The diet of the Augustinian canons has been suggested to be less strict than that of other religious orders (Brooke, 2003), and if the houses of Gilbertine canons were largely similar to those of Augustinian canons then the high caries prevalence seen here might reflect this. Alternatively all groups could contain high status burials. However, the Gilbertine burial grounds were open to both rich and poor (Golding, 1995) and it is unclear which group of individuals this sample represents.

7.9.1.4.2 Teeth from Adult Male and Female Subdivisions.

The similarities between Benedictine and Carmelite samples continue when the caries prevalence of males and females are examined. The caries prevalence of male teeth in both groups is similar and particularly low (B = 2.3%, C = 2.8%), and although the caries prevalence of the female teeth is significantly higher in both groups (B = 5.7%, C = 5.4%), the prevalence rates are similar and not high when compared with the other monastic samples, or with the prevalence rate seen in the church sample of the period. In fact the caries prevalence for the female teeth is very similar to that for the adult teeth from the church sample (5.7%, without Rivenhall). Does this indicate burial of the general population at these sites? Unfortunately the data for differences in caries prevalence for the Late Medieval church sample are considered too unreliable to provide a useful comparison. Alternatively, the low caries prevalence in the male teeth might indicate that dietary regulations were being observed in the monastic population, but this assumes that the male sample includes a reasonable proportion of the monks and there is no evidence that this is the case for either group.

The Augustinian and Dominican samples differ slightly in the sex pattern of caries prevalence. Whereas the Dominican sample has significantly higher caries prevalence in female teeth (9.6%) than male teeth (7.7%), the Augustinian sample has significantly higher caries prevalence in the male teeth (7.9%) than the female teeth (5.6%). The latter is unusual in that caries prevalence is usually higher in females, and it was the only monastic order to show this trend. The Gilbertine sample had significantly higher caries prevalence in the female teeth (16.0%) than the male teeth (10.9%). It is possible that the Gilbertine and Dominican samples represent a combination of religious males and wealthy males, with the wealthy males consuming a more cariogenic diet than that consumed by the religious. In contrast the females in the group may be predominantly wealthy, and so their prevalence rate (undiluted by the effect of a religious lifestyle of some individuals) is higher than that of the males. The caries prevalence of the Augustinian female sample is equivalent to that of the Benedictine, Carmelite and church samples. Does this imply that the females in the Augustinian sample were of lower status compared to the males? Without better data these questions will have to remain unanswered.

7.10 Location: Coastal and Inland.

7.10.1 Main Periods: Early Medieval; Middle Medieval; Late Medieval.

In the Early and Middle Medieval Periods the inland samples, in terms of number of skeletons and number of sites, were larger than the coastal samples. In the Late

Medieval period it was the coastal sample that had the largest number of skeletons, and the individual coastal data-sets were usually larger. The Early Medieval coastal data-sets averaged 132.0 skeletons, with a maximum of 199, and 62.5% (5 of 8) contained more than a hundred skeletons. In comparison the Early Medieval inland data-sets averaged 95.9 skeletons, with a maximum of 222, and only 46.7% (7 of 15) comprised over a hundred skeletons. There was only one Middle Medieval coastal site (School Street, Ipswich, numbering 95 skeletons), but the inland sample had a mean of 158.4 skeletons per data-set (maximum 363) and 62.5% (5 of 8) contained over a hundred skeletons. Ninety percent (9 of 10) of the Late Medieval coastal sites had over a hundred skeletons, and the mean number per data-set was 341.3. In comparison the inland sample averaged 181.5 skeletons per data-set and only 36.4% (4 of 11) numbered over a hundred. The main reason for this discrepancy probably lies in the distribution of the cemetery types. The Late Medieval inland sample contained four of the ten monastic sites, two of which were below a hundred skeletons. The remaining six monastic sites were all above a hundred skeletons and all were on or near the coast. In addition the inland sample contained the majority (5 of 7, 71.4%) of the church data-sets, which tended to be smaller than the monastic samples.

7.10.1.1 Proportions of Adults and Subadults.

Both coastal and inland Early Medieval samples show proportions of adults and subadults close to 70:30, implying that there are no major differences between both groups. The Middle Medieval sample again differs from the 70:30 ratio in both coastal (although this only consists of one site) and inland groups. Whereas the coastal Late Medieval sample has proportions of adults and subadults close to 70:30, the inland sample does not, being closer to 76:24. This appears to be the opposite of what might be expected, considering more of the church samples are located inland, and more of the monastic samples are on the coast. However, the inland sample does contain two of the three hospital samples, and these had a more extreme under-representation of subadults than did the monastic sample (see Section 7.7.1.1). When the inland and coastal monastic and hospital groups are compared it can be seen that in both cases the group with the lowest proportion of subadults is the inland group.

7.10.1.2 Sex Distribution.

In general the same trends are present when each main period was considered as a whole. Both inland and coastal Early Medieval samples have equal distributions of males and females, which reinforces the impression that there are no major differences between these two groups. The Middle Medieval inland sample had proportionally more males than expected, although the reasons for this are still unclear. The coastal sample had almost identical proportions of males and females as the inland sample, but was probably not found to be significant on account of its small sample size. Both inland and coastal Late Medieval samples had a significantly high number of males, which is due to the presence of monastic and hospital sites in each group

7.10.1.3 Age Distribution.

7.10.1.3.1 Adults in General.

The age distribution of the coastal and inland Early Medieval samples were significantly different: the coastal sample had a higher proportion of individuals in the two older age groups, while the inland sample had a higher proportion in the two younger age groups. The reasons for this are unclear. In contrast, the age distributions of the Middle Medieval coastal and inland samples were not significantly different, although the inland sample of this period also had a larger proportion of individuals in the two younger age groups than did the coastal sample. There was no significant difference between the age distributions of the coastal and inland Late Medieval samples.

7.10.1.3.2 Adults: Male and Female Subdivisions.

In no period was there a significant difference between the age distribution of males and females within the coastal or inland samples, although in the coastal samples for all three periods there was a higher proportion of males in the two older categories and considerably more males in the Middle Medieval coastal sample were placed in the Old Adult category than were females. In contrast, for two periods (Early and Late Medieval) the inland group had more females in the two older age groups than males.

As for the adult age distributions, the male and female age distributions of the coastal Early Medieval group were significantly different from the distributions of the inland group. For both sexes there were more individuals in the two older age groups in the coastal sample than in the inland sample. The male and female age distributions of the Middle Medieval groups also mirrored that of the adult individuals, and there were no significant differences between coastal and inland sample for either sex, even though the coastal males had a particularly high proportion of individuals in the Old Adult age group compared to the inland males. Whilst the age distributions of the coastal and inland females were not significantly different in the Late Medieval period, although the inland females had a slightly higher proportion of individuals in the two older age groups, there was a significant difference between the age distributions of the coastal and inland males. There were proportionally more males in the Old Adult, and fewer in the Young Adult age groups in the coastal sample than the inland sample.

7.10.1.4 Caries Prevalence.

7.10.1.4.1 Teeth From Adults.

In the Early Medieval period the coastal sample had significantly lower caries prevalence (3.5%) than the inland sample (6.0%) in spite of the fact that the inland sample contained a large number of individuals in the two younger age groups and the coastal sample had more in the two older age groups. No significant difference was observed in the Middle Medieval period, although the coastal prevalence rate was slightly higher (10.0%) compared to the inland prevalence rate (9.1%). The age distributions of these two samples were not significantly different, although the inland sample did have more individuals in the two younger age categories, which might be expected to result in lower caries prevalence. In the Late Medieval period the inland caries prevalence, at 7.4%, is significantly lower than the coastal prevalence (8.9%), but there were no significant differences in age distribution. Within each group the same overall temporal trend was noted, with the Late Medieval samples having a higher prevalence rate than the Early Medieval samples, but the increase was greater in the coastal group than in the inland group.

Previous studies of archaeological populations have noted a lower caries prevalence in coastal compared to inland populations, or in populations consuming a marine-based diet to those consuming a terrestrial plant-based diet (Larsen, 2000; Larsen, *et al.*, 1992; Storey, *et al.*, 2002; Littleton and Frohlich, 1993; Fooce and Sciulli, 2003). This difference is usually attributed to the higher protein content of the coastal diet based on marine produce and the higher carbohydrate content of the inland foods, where plant foods make up a larger portion of the diet (see Section 3.4.3). In addition, Walker (1986) attributed the lower caries prevalence observed with a marine-based diet in part to the high fluoride content of seafood. The difference in prevalence rate observed between the coastal and inland Early Medieval samples is consistent with that found in previous studies, and is unlikely to be due to differences in age structure of the two groups as the sample with the lowest caries prevalence has the highest proportion of older individuals and vice versa. However, the opposite trend is seen in the Late Medieval sample and there is no difference between the prevalence rates of the Middle Medieval period. The possibility that these trends may be related to the consumption of sea fish and other marine resources is explored below.

There is some debate over the extent of fish consumption in the Early Medieval period. Bond (1988) has suggested that fish eating declined after the fifth century, but that the practice was restored and encouraged by the church. The observance of fast days, where fish was consumed instead of meat, began around the seventh century in Kent, and spread throughout the rest of Britain (Hagen, 1992). Hagen (1992: p69) proposed that: "Inhabitants of coastal districts would probably have included more salt-water fish and shellfish in their diet. Those living near large rivers or lakes would probably have consumed a fair proportion of fresh-water fish, including eels". Since fish were difficult to preserve, the large-scale transportation of coastal fish inland was not possible, and sea fish were unlikely to form a substantial part of the diet of people not living on the coast (Steane and Foreman, 1988). However, at the mid-to-late Saxon site of Flixborough, Lincolnshire, the fish bones were dominated by freshwater and migratory species, including eel, smelt, flounder/plaice, pike, cyprinids, perch and salmonids, and although marine fish are present they only occur in small numbers (Barrett, 2002). The general lack of fish bones from Early Medieval sites is commented upon and it is suggested that fish are rarely found in rural Anglo-Saxon sites and so were not regularly consumed; where fish are present the assemblages are usually dominated by freshwater fish, with few marine fish present.

In a review of the fish remains from the southern North Sea region between the first and sixteenth centuries AD, Enghoff (2000) discussed the evidence from the east coast of England. She reports that at Lincoln, 50 km from the coast, freshwater fish and eel predominate throughout the Early Medieval period, but at coastal Southampton all the fish bones are from marine fish. In Early Medieval sites in York there are a mix of marine, freshwater and migratory fish, but freshwater and estuarine fish are dominant. The marine fish consist mainly of herring, which shoal close inshore in the summer. The herring industry began around AD 495, based on seasonal exploitation, and she observes that until the end of the first millennium most fish are caught locally. Coy (1996) also suggests that fish were local catches in Saxon Southampton. Huntley and Stallibrass (1995) have reviewed the data on animal bone from Jarrow, Monkwearmouth, Lindisfarne and Hartlepool (all coastal sites in North East England). Like Enghoff, they noted a general mixture of freshwater, estuarine and inshore marine fish, although the abundance of fish varied. At Jarrow there were few fish bones, but the majority present were sea fish, although they do point out that the lack of sieving may have biased against the retrieval of the smaller freshwater fish bones. Most of the fish at Monkwearmouth were cod (marine), and Lindisfarne had an abundance of fish remains amongst the animal bone, with marine fish being especially important. At Hartlepool there was a mix of freshwater, estuarine and some inshore marine fish. Aston (2000) also notes the presence of coastal fish at Hartlepool. Few fish bones were recovered from the early *monasterium* phase at Whithorn, but the presence of fish-hooks and possible line-weights is taken as evidence that deep sea fishing was practiced (Hill, 1997). However, all these sites are monastic, so they may not necessarily be representative of the usual fish species consumed on Early Medieval sites.

In conclusion, the fish bone evidence suggests that although fish might not have been consumed on such a large scale as occurred in Later Medieval times, it seems as though the remains of marine fish are generally confined to coastal sites and that freshwater fish were consumed inland. Documentary evidence also shows that sea fish were caught: the *Colloquy of Ælfric* includes a conversation with a fisherman, who mentions that he sometimes ventured to sea to catch herrings, salmon, dolphins, sturgeon, oysters, crabs, mussels, winkles, cockles, plaice, flounder and lobsters (Cameron, 1993). Stable isotope analysis has often been used to investigate the marine versus terrestrial based diet (Ambrose, *et al.*, 1997), and has the potential to contribute vital data to the understanding of marine food consumption in the Early Medieval period, but unfortunately few published studies have been conducted on British material. A study of the carbon and nitrogen isotope ratios in the skeletal material excavated from Berinsfield, Oxfordshire (inland), provided no evidence that marine foods were consumed, but did show that freshwater fish were probably consumed by the majority of the population (Privat and O'Connell, 2002).

An intensification and expansion of marine fishing is widely recognised towards the end of the Early Medieval period, and Aston (1988: p3) has highlighted the importance of marine fish in the general Late Medieval diet, "both in terms of the numbers of fish represented and weight of meat implied". The consumption of fish was encouraged by the church, which declared a considerable proportion of the year to be fast days, including the 40 days of Lent, 40 days of Advent and 40 days following Pentecost, as well as the eves of other Christian festivals, and Fridays, Saturdays and sometimes Wednesdays (Hagen, 1992; Barrett, 2002). Fish remains from various sites in York attest the move from predominantly riverine and estuarine fish to deep-sea fish, with the rise in importance of herring in the eleventh and twelfth centuries followed in later periods by an even greater focus on herring and some gadids (cod, haddock, ling and whiting). The increasing dominance of marine fish in York fish bone remains culminates in a fifteenth-to-sixteenth century assemblage consisting entirely of marine fish (Enghoff, 2000). Enghoff also observes this dominance of marine fish in Late Medieval assemblages at other locations, including London, Norwich, Great Yarmouth and King's Lynn (both the latter were exclusively marine), Canterbury, Newcastle-upon-Tyne, Little Pickle (Surrey), and from the food stores of the Mary Rose. The latter were all processed cod, with their heads and first six vertebrae removed, probably representing dried 'stockfish'.

Huntley and Stallibrass (1995) report evidence for an intensification of marine fishing in the north-east of England in the Late Medieval period. Fish bones from Newcastle-upon-Tyne and Hartlepool attest to the development of a major fishing industry based on deep-sea fish; marine fish are found in food debris from a fifteenth century drain at Barnard Castle; an abundance of marine fish are present in Late Medieval Jarrow, Monkwearmouth and Lindisfarne, and also Jedburgh Priory, where marine fish dominate the assemblage even though the fills from three pits were carefully sieved to make sure no evidence for smaller freshwater fish was lost. They conclude that nearly all Late Medieval sites show more variety in fish species implying greater exploitation of coastal resources. Coy (1996) also found a wider array of species in Late Medieval Southampton compared to those present in the preceding periods, and suggests that some of these could have arrived through trade. At Langport, Somerset, the fish assemblage consisted entirely of marine species, with the exception of eels, and include: hake, ray, gunnard, sea bream, grey mullet, plaice and other flat fish (found around British shores); herring and mackerel (shoal inshore at certain times of the year, otherwise in moderately deep water); and cod, haddock, ling and hake (all deep-water fish) (Grant, 1988).

The gadids (cod, haddock, ling and whiting) first appear at coastal sites, cod usually earlier than haddock as it approaches closer inshore, and after better methods of processing and preserving fish were developed their remains are found inland (Enghoff, 2000). She observes that haddock first begin to appear inland around the tenth to twelfth centuries all over the Baltic and North Sea region; for example, fish trade developed in Sweden during the end of the Viking period (c. 900-150 AD) encouraged by both the Hanseatic League and the church (Sten, 1995). As well as improved preservation, the development of better technology and ships allowed this increased exploitation of deep sea fish (Steane and Foreman, 1988). Documentary evidence also shows that marine fish travelled far inland, and that dried sea fish must have been a common source of food (Aston, 1988; Bond, 2004, 1988). For example, the fifteenth and sixteenth century brokage books from Southampton provide information on the extensive trading of fish inland, although some of the fish mentioned in the documentary sources are rarely found on archaeological sites and vice versa (Coy, 1996). Analysis of carbon stable isotopes from five sites in north-east England showed that marine foods were even forming part of the diet of peasants in remote rural settlements such as Wharram Percy (Mays, Simon A., 1997). Throughout the Late Medieval period the consumption of marine fish far outweighed the amount of freshwater fish, and it appears that the latter became regarded as a high status food, being more expensive and given as gifts (Dyer, 2000, 1988). Documentary evidence shows that marine fish made up 64-99% of fish consumption in wealthy households (Dyer, 2000, 1988). Dried cod ('stockfish') and herring were cheap and available to the poor (Bond, 2004, 1988). Fish also feature prominently in Medieval recipe books (Black, 1992; Cosman, 1976; McKendry, 1973).

Fish are not the only source of marine food that may be rich in fluoride: sea mammals, molluscs, shellfish, crustaceans and sea birds may also contain this trace element. Sea birds were exploited as food on the Isle on Man, and their bones display evidence of being cut, cooked and chewed (Fisher, 1997). Marine molluscs, crustaceans and birds, as well as fish, formed an important part of the diet at Lindisfarne, a variety of estuarine and coastal birds were found at Jarrow, and sea birds have also been discovered in the faunal assemblages at both Church Close and Middlegate, Hartlepool (Huntley and Stallibrass, 1995). Shellfish and molluscs, such as mussels, periwinkles, limpets, cockles and oysters have been found on Early Medieval sites (Hagen, 1995), and shellfish collection appears to have been organised on a commercial scale by the end of the tenth century (Bond, 1988, 2004).

Even if marine food was consumed, different parts of fish contain different amounts of fluoride, with bone containing higher concentrations than the flesh (Camargo, 2003; Julshamn, *et al.*, 2004; Edgar, 1990b). It has been suggested that considerable amounts of fish flesh would have to be consumed in order to gain any real benefit, and it has been considered unlikely that this would occur (Fabian Society, 1975). However, this comment was made in relation to recent British populations, and clinical studies of modern populations where marine products regularly form a considerable part of the diet have concluded that the fluoride content of marine foods does contribute to low caries prevalence (Kimura, *et al.*, 2001). In addition, if the fish bones were to be consumed as well as the flesh then this would mean that a larger amount of fluoride would be ingested. Crushed and flattened fish bones have been recovered from cesspits at the site of St. Andrew Fishergate, York, and these have been interpreted as "having been ingested by people in the course of eating" (O'Connor, 1991: p263; Enghoff, 2000). Jones (1986) conducted experiments on the effect of consumption by three different mammals (human, pig and dog) on the bones of medium-sized fish (herring, mackerel and haddock), finding that less than 10% of the bone survived ingestion and, of those that did, some were crushed in an identical manner to those found at St. Andrew Fishergate. Coy (1996) has suggested that since small eel and herring bones are frequently found in cesspits, concentrations of these could be interpreted as the presence of cess. In addition to the archaeological evidence, there are instructions in Medieval recipe books for preparing broth and stocks through boiling fish bones (McKendry, 1973; Cosman, 1976). Even though one Medieval recipe for the preparation of a fish dish instructs that the fish bones should be picked out part way through the cooking process (McKendry, 1973) it appears that consumption of fish bones, or the use of fish bones in the preparation of other foods, was a regular occurrence when fish was part of the diet.

Overall the evidence for the Early Medieval period suggests that coastal populations did consume some sea fish, but that the inland sites were restricted to freshwater fish from rivers, lakes and ponds. This would tie in with the data on dental caries, as the lower caries prevalence in the Early Medieval coastal sample might indicate the regular consumption of fluoride-rich marine fish, a resource that was largely unavailable to those inland. The development and intensification of deep-sea fishing from around the eleventh century onwards, coupled with improved methods of processing and preservation, resulted in the availability of a large quantity of sea fish, which was transported far inland. Dried cod and salted or smoked herrings, being cheap, were widely available to the general population. The fact that the difference in caries prevalence disappears in the Middle Medieval sample, and that the coastal sites no longer show a lower caries prevalence in the Late Medieval period, would be consistent with this development. However, Mays (1997) found that marine food consumption was higher in some coastal populations (but not all) in the Late Medieval period than in inland populations, so it is possible that coastal populations would still be consuming more sea food than those inland. These conclusions must be regarded as extremely tentative as the data on which they are based have many flaws. The lack of isotope studies is regrettable as this could help resolve the question of how much marine produce was being consumed, when, where and by whom. Many of the fish bone assemblages have come from sites excavated before sieving was standard practice and consequently much information has been lost. The data on dental caries is also limited by the fact that they have been collected from skeletal reports prepared by a variety of individuals through different decades; the potential for intra observer error is high. In addition it has been virtually impossible to properly account for variations in age distribution between samples, so the author cannot be certain that these differences are real. The problems of comparability have meant that only the most basic data could be collected and compared; more informative conclusions could no doubt be drawn from more detailed and accurate data.

7.10.1.4.2 Teeth from Adult Male and Female Subdivisions.

The Early Medieval data for male and female teeth is consistent with that observed for the adult teeth, with the coastal samples having a lower caries prevalence than the inland samples even though both coastal samples had a high proportion of older adults, and also with that observed in the Early Medieval period in general, with no difference in caries prevalence between the sexes. This similarity suggests that there were no differences in diet between the sexes in either coastal or inland populations, and that if marine produce is being consumed on the coast (and really is linked to the lower prevalence of caries) then both sexes have equal access. The similarity of diet between the sexes in an Early Medieval inland population was suggested by stable isotope analysis at Berinsfield, suggesting that both sexes consumed similar amounts of animal protein, although it was not possible to distinguish between animal protein consumed as meat and that consumed as dairy produce, or observe any variation in the quality of foods consumed (Privat and O'Connell, 2002).

In the Middle Medieval period there was only a small (not significant) difference between the coastal and inland female teeth, but the male inland teeth had a much lower caries prevalence than the coastal male teeth. There were more males in the two older age groups in the coastal sample, but the age distributions of the two groups were not significantly different. In addition the difference in caries prevalence between the sexes in both groups was significant. These differences are interesting, but it is difficult to interpret what they mean. The similarity between the coastal and inland female caries prevalence may suggest that both groups are eating a similar diet, which may perhaps be related to the emergence of inland trade in marine food. The low caries prevalence in inland males compared to inland females may imply that this marine food could have been more accessible to males, but without other evidence (such as stable isotope data) this is pure speculation. Why the coastal males should have caries prevalence higher than both the inland males and inland females is unclear.

In the Late Medieval period both male and female teeth have a higher caries prevalence in the inland sample than in the coastal, the opposite of what occurred in the adult teeth. This difference was not significant for male teeth, but was significant for female teeth, and whilst the male age distributions were significantly different from each other (more older adults in the coastal sample), the female age distributions were not. Mays (1997) observed that some coastal populations did appear to consume more marine food in the Late Medieval samples he examined, which might be supported by the lower caries prevalence in the coastal female teeth seen here. However, since the data for the adult teeth showed a higher caries prevalence in the coastal teeth these data are difficult to interpret. As in the data for the Late Medieval period as a whole, the female caries prevalence was higher than the male in both coastal and inland samples, although this difference was only significant in the inland group. There were no significant differences in age distribution between the sexes within each sample. In the Late Medieval period it seems as though inland females have a significantly higher caries experience than both inland males and coastal females. Does this imply marine fish were available to both sexes equally on the coast, but that males consumed more of the marine produce that travelled inland? Again, there may be many other reasons to account for the variations in caries prevalence observed here, and the Late Medieval sample is complicated by the differences observed between different cemetery types, although church, monastic and hospital sites are found in both groups.

7.11 Regional Division.

7.11.1 Early Medieval Period: Regional Variation.

The South East sample had the smallest number of skeletons, but this is not surprising as there were only two sites in this region. One of the data-sets had over a hundred skeletons, and the mean was 123.0 skeletons. The group with the highest mean number of skeletons per data-set (153.3), and also the largest percentage of sites with over a hundred skeletons (66.7%, 2 of 3), was the North/North West region. In comparison the Far North and Central Southern regions both had a fairly low mean number of skeletons per data-set (FN = 97.8, CS = 94.1). The Far North also had the lowest percentage of sites with over a hundred skeletons (2 of 5, 40.0%), whilst 57.1% (4 of 7) of the Central Southern data-sets had more than a hundred skeletons. It seems as though the Far North samples tended to be smaller than those from the other regions, which may possibly relate to poorer conditions for preservation.

7.11.1.1 Proportions of Adults and Subadults.

Three of the Regions in the Early Medieval period show a distribution close to 70% adults and 30% subadults, including the Far North, Central Southern, and South East regions. The North/North West region diverges slightly, with 34% of the sample being subadults. The Eastern/Central Eastern group diverges in the opposite direction, with only 25% of the sample consisting of subadults. It is unclear why the sample for these two regions should contain either more or fewer subadults than in the other regions.

7.11.1.2 Sex Distribution.

All but one of the Early Medieval regions had a normal sex distribution except for the Central Southern region, which had a slightly higher proportion of females (55.8%) and was found to be significantly different at the 5% level. However, this group was not found to be significantly different from the majority of the other regional groups. On balance it seems as though a cross-section of the population is represented in all regions.

7.11.1.3 Age Distribution.

7.11.1.3.1 Adults in General.

The age distributions of the samples from the different Early Medieval regions generally seem to have been similar to each other, and only two samples were found to be significantly different from each other: the Far North and North/North West. The latter was the only group to have more individuals in the two older age groups, and it also had the highest proportion of individuals in the Old Adult category and lowest proportion in the Young Adult category. In contrast, the Far North had the largest proportion of individuals in the two younger age groups combined and the lowest percentage of individuals in the Old Adult group.

7.11.1.3.2 Adults: Male and Female Subdivisions.

Within none of the regions were there significant differences between the age distributions of the males and females. The age distributions of the males were not significantly different between the regions, but the age distribution of the Far North females was significantly different from the Eastern/Central Eastern and the Central Southern regions. Whereas the age distributions of the males and females in all other regions were similar to that of the adults, the male and female Far North age distributions were different from that of the adults; a high proportion of males and females were found in the two older age groups, especially the Old Adult group, whereas the majority of the adults were placed in the two younger age groups. This can be attributed to the fact that only two of the five sites in this region provided data on caries in male and female teeth, one of which was Jarrow A, a monastic site with a particularly high proportion of individuals in the older age groups (see Section 7.8.2.3). In comparison, the only other region to have fewer sites provide data on male and female teeth than on teeth from adults was the Central Southern region, and only one of the seven sites neglected to give this information.

7.11.1.4 Caries Prevalence.

7.11.1.4.1 Teeth From Adults.

There have been no real studies of geographical variations in caries prevalence in Britain. Although Freeth (1999) addressed geography in her thesis, the sites she studied were all located in the south of England, and the seven sites included were distributed between three time periods (Romano-British, Anglo-Saxon, and Medieval). These sites were each studied individually with regard to their location, rather than investigating differences or similarities that might be present between regions. With only two or three sites for each time period, such an approach would be impossible. Since data for a considerably larger number of sites has been collected for this study, division of sites into different regions has been possible. Although the division employed is somewhat basic, since sites are grouped simply according to location without consideration of other factors such as proximity to major rivers or towns, or the presence of roads or trade routes, this was attempted as a first step to identify any trends that could be investigated in more detail and with better data in future. The advantage of Freeth's (1999) research is that she studied a combination of dental diseases, and thus was able to draw more detailed conclusions concerning aetiological factors. Even more valuable was the fact that she was able to collect all her data herself, and thus obviate the problems of inter-observer error (although intra-observer error might still remain) and the lack of detailed data; through this approach she was also able to relate both age-at-death and sex directly to the caries prevalence rates observed within the samples. Such an approach is possible for the study of a limited number of sites, but not when data for a large number need to be incorporated (Ortner, 1991). Thus any study attempted on a large scale, such as this one, has to rely on the inconsistent, less detailed and incomplete data already available, with an unknown level of accuracy and error. As there have been no other regional studies in Britain, there are no data available with which to compare the results of this section.

Freeth (1999) notes that geoclimatic variables, including the mean hours of sunshine temperature, relative humidity rainfall, latitude and distance from the coast, can affect caries prevalence. These interlinked factors probably exert their effect through their influence on the economy and cultural practices of the population (although the latter may partly be influenced by the marine content of coastal versus inland diets), with the type of farming practiced (proportion of arable and livestock), and type of crops grown or animals raised, dictated by the nature of the climate and landscape (Dark, 2000; Fowler, 2002). The local crops and animals available determine the food content of the diet in an era where large-scale trade of goods does not occur, and in the Early Medieval period, Freeth (1999) proposes that geographical variability in caries prevalence will reflect the availability of local resources. Since trade in exotic food items is likely to be minimal, she suggests that the diet consumed will be largely egalitarian. However, the data obtained from stable isotope studies of the Berinsfield population suggested that a difference in diet was present between groups of different status, with those classed as wealthy consuming more protein in the form of herbivore meat and/or dairy products and those classed as poor consuming more meat from omnivores (possibly pigs), river fish and other freshwater animals (Privat and O'Connell, 2002).

Britain can be divided into a highland and lowland zone, with the highland zone lying west and north of a line following "an irregular course from the mouth of the River Tees in the north-east to the north of the River Exe in the south-west" (Howe, 1997: p33). The highland zone is characterised by mountains, thin acidic soils prone to waterlogging, and a harsh climate of cooler temperatures, increased rainfall and snowfall, wind exposure and less sunshine. In contrast, the lowland zone is generally considered to be more favourable for human habitation (Howe, 1997; Rackham, 2000; Reed, 1990). These broad distinctions obscure the diversity of habitat present within each region, but the division remains a useful abstraction nevertheless (Reed, 1990). In the Early Medieval period the lack of favourable climatic and topographical conditions in the north and west of Britain meant that arable farming was difficult; in Scotland cultivated strips (or 'rigs') had to exist on pockets of better land distributed among the less-fertile rocky pasture, and an increased emphasis on pastoralism in these areas is likely (Reed, 1990). Oats replaced wheat, barley and rye in the human diet (Reed, 1990; Galloway, 1998; McKendry, 1973; Drummond and Wilbraham, 1957), and it is likely these were a dietary staple in the form of oat cakes, oatmeal porridge and ale brewed from oat malt, much as they were in these regions in Later Medieval Britain (Dyer, 1998).

In all regions, the caries prevalence of the Early Medieval period is reasonably low, which is consistent with what is known of the diet of the time (see Section 7.6.1.4). However, two of the regions both have a significantly lower prevalence rate: the Far North at 3.5% and the Eastern/Central Eastern at 2.9%, but since the age distribution of the Far North sample had the highest proportion of individuals in the two younger age categories, and the least in the Old Adult group, the influence of age distribution on caries prevalence cannot be discounted. The Far North region encompasses all the sites in the highland zone, and it is possible that the restrictions on arable farming in this area and the different crops cultivated have resulted in a less cariogenic diet. Since oats were the staple cereal it would be interesting to know whether they are less cariogenic than wheat, as wheat has been suggested to be more cariogenic than both rice and maize (Sreenby, 1983). Alternatively, the different methods of preparing the different cereals for consumption could have affected their cariogenicity. Again, it is not known whether oats in the form of oatcakes or porridge were more or less cariogenic than wheat in the form of bread or pottage. If animal products formed a more important part of the diet in the highland zone due to the difficulties of crop growth this could also have affected the cariogenicity of the diet. A higher proportion of protein in the diet will reduce the risk of caries, as will the consumption of dairy produce. Another factor that must be considered is the fact that the majority of the sites in this region were located on the coast and it is probable that the tendency for coastal sites to have lower caries prevalence in this period has affected the results. A comparison with inland sites of the area would be required to resolve this issue, but since the conditions for preservation are unfavourable in the highland zone inland sites are scarce. In addition, the Far North region contains both Early Medieval monastic sites, which have been noted to have significantly lower caries prevalence than those of the non-monastic sample (Section 7.8.1.4), and this could be an additional reason for the low caries prevalence for this region. This does raise the question: is the caries prevalence of the monastic sample low because of the northerly location, or is the low caries prevalence of the Far North sample low in part because of the presence of monastic sites in the sample?

The North/North West, Central Southern and South East regions were all similar in terms of caries prevalence, and although the South East prevalence was significantly lower than that of the Central Southern sample, the North/North West sample was not different from either. In both Central Southern and South East regions there were more younger adults in the sample, but in the North/North West there were more older adults, which might be expected to raise the caries prevalence. In all three regions there was a considerable proportion of inland sites; the Central Southern region (caries prevalence 6.5%) consisted entirely of inland sites, whereas two thirds of the North/North West sample (caries prevalence 6.2%) and half the South East sample (caries prevalence 5.1%) were inland sites. It is interesting to note the descending caries prevalence as the proportion of inland sites decreases within each region. Coupled with the much lower caries prevalence in the Far North, where only a fifth of the sites were inland, this suggests that a large proportion of the apparent regional variation in the Early Medieval period may in fact be due to variations in the ratio of coastal to inland sites within each region.

Two thirds of the Eastern/Central Eastern sites are inland, yet this sample has the lowest caries prevalence of all (2.9%). Although this group does have a higher proportion of adults in the two younger age groups than in the older groups, this distribution is not significantly different from any other region. One possibility might be the proximity of two of the inland sites to the edge of the Fens, although drainage and land reclamation may have altered the extent of the Fenland since Early Medieval times (Silvester, 1999). In Late Medieval times the Fenland was more suited for the pasture of animals than the growth of crops, and in addition there would have been a larger availability of fish (Dyer, 1989); it is likely that similar subsistence patterns existed in the preceding periods. If so, then the diet may have contained a larger proportion of dairy produce, which is protective against the development of caries, and protein (especially fish), which does not place the teeth at risk. However, all these regional trends in caries prevalence require further investigation using better data to determine whether or not real variation exists, and if so to examine what this might mean for the diet of the populations concerned.

A further possible cause of regional differences in caries prevalence is variation in the type and quantity of trace elements in the soil and water (see Section 3.3.4). Of the trace elements, fluoride levels in drinking water are likely to have most impact on caries prevalence. Few areas of Britain have modern natural fluoride levels high enough to have a noticeable effect on caries prevalence, and Wales and Scotland have particularly low levels, but some areas, especially in the north east of England, do have naturally high levels of fluoride. Unfortunately it was not possible to investigate any possible associations between fluoride and caries prevalence in the course of this study (see Section 7.2.4), but it might be interesting to attempt in future. However, any such study will have to rely on modern data, which are not necessarily equivalent to the fluoride levels of the past, and depend on obtaining comparable skeletal collections from both high and low fluoride areas. Since high fluoride areas are not common in Britain this limits the potential for study. It is also known that certain areas of modern Britain (for example parts of Somerset) have a high level of molybdenum in the soil (Anderson, 1969), but unfortunately data on soil trace element content is not easily available. Even if it were, it would reflect modern values that could well have changed over time.

7.11.1.4.2 Teeth from Adult Male and Female Subdivisions.

In none of the Early Medieval regions were there significant differences in caries prevalence between male and female teeth. This is consistent with the results obtained for the Early Medieval period in general, and is further evidence that there were no major sex differences in diet. The caries prevalence for both sexes follows the same trends as that observed for adult teeth.

7.11.2 Middle Medieval Period: Regional Variation.

The Eastern/Central Eastern region was best represented with a total of 945 skeletons from seven sites, a mean of 135 skeletons per data-set. Three (42.9%) of these sites had over a hundred skeletons. The remaining two regions with skeletal material (North/North West and Central Southern) were both only represented by one site each, so it is difficult to draw comparisons, but both sites had over a hundred skeletons.

7.11.2.1 Proportions of Adults and Subadults.

Only one of the Middle Medieval regions, the Central Southern region, has a sample consisting of 70% adults and 30% subadults. In the other two regions for which samples are available subadults make up 37% of the sample. This is consistent with the pattern observed for the Middle Medieval period in general.

7.11.2.2 Sex Distribution.

Only two regions provide data on caries prevalence in male and female teeth in the Middle Medieval period. Both regions show a higher proportion of males, although only the Eastern/Central Eastern group is significantly different from a normal distribution despite the fact that the North/North West group actually has a higher proportion of males (58.0%). This could be due to the small sample size available for this region. Again, the trend towards a higher proportion of males is unexplained.

7.11.2.3 Age Distribution.

7.11.2.3.1 Adults in General.

There was a significant difference between the age distributions of the two regions for which this could be compared. The majority of the adults in the North/North West sample were placed in the two younger age groups, especially the Young Adult category, with a small proportion found in the Old Adult group. The Eastern/Central Eastern sample had a more even distribution of individuals among the age categories. The uneven distribution in the North/North West group may reflect the fact that only one data-set was available for this region, whilst seven provided data for the Eastern/Central Eastern region.

7.11.2.3.2 Adults: Male and Female Subdivisions.

The age distributions of the males and females of the North/North West group were similar to that for the adults in this group, with a high proportion of individuals in the Young Adult age group and a small proportion in the Old Adult group, although the females had more individuals in the two older age groups combined than did the males. Despite this difference, the age distributions of the two sexes were not significantly different, which might be a result of the small sample sizes. The females in the Eastern/Central Eastern group had a higher proportion of individuals in the two younger age groups than did the males, with fewer in the Old Adult category. This difference was significant.

The age distributions of the females was not significantly different between the two regions, both having a higher proportion of individuals in the two younger age groups than in the older. However, the male age distributions were significantly different, as the North/North West group had considerably more males in the younger age categories, and fewer in the Old Adult age category, than did the Eastern/Central Eastern group.

7.11.2.4 Caries Prevalence.

7.11.2.4.1 Teeth From Adults.

Regional comparison of caries prevalence in the Middle Medieval period is hampered by the lack of data for most of the regions. Only the Eastern/Central Eastern region contains a reasonable number of sites, and the remaining two regions with data provided are represented by only one site each. Since one of these is Trowbridge, and the reliability of this data has been questioned above (Section 7.6.1.4), this leaves only two regions to compare. Since the Eastern/Central Eastern sample contains the majority of the sites it is not surprising to find that the caries prevalence (6.1%) is similar to that for the Middle Medieval sample as a whole (5.8% without Trowbridge). The caries prevalence of the North/North West region was significantly lower (4.3%), but the age distribution of this sample was significantly different from that of the Eastern/Central Eastern sample, containing an extremely large proportion of Young Adults and a tiny proportion of Old Adults. It is considered likely that this age distribution is responsible for the difference in caries prevalence.

7.11.2.4.2 Teeth from Adult Male and Female Subdivisions.

In the Eastern/Central Eastern region there was no significant difference between the caries prevalence rates for male (6.1%) and female (5.8%) teeth, which again is consistent with the data for the Middle Medieval period as a whole. In contrast, the caries prevalence rate of the female teeth in the North/North West sample was significantly higher (7.9%) than that of the male teeth (2.2%). These data come from one site, so cannot be regarded as representative of the region as a whole, and it is unclear at present what this difference may mean, beyond the fact that the females were consuming a more cariogenic diet than that of the males.

7.11.3 Late Medieval Period: Regional Variation.

The largest regional samples for the Late Medieval period came from the Far North and North/North West regions, but these are the regions that contain the two sites with the most skeletons: Whithorn B (Far North, 1605 skeletons) and St. Helen-on-the-Walls (North/North West, 1037 skeletons). If these sites are included, then it appears that these two regions tend to have sites with large skeletal samples: the Far North averages at 319.4 skeletons per data-set, with 75.0% (6 of 8) containing over a hundred skeletons, and the North/North West has a mean of 293.8 skeletons per data-set, and 50.0% (3 of 6) number over a hundred. However, if these sites are excluded then it brings the averages down to levels comparable with the other regions. Without Whithorn B, the Far North has a mean of 135.7 skeletons per data-set, and 71.4% (5 of 7) data-sets have over a hundred skeletons (which is still high). The North/North West has a mean of 145.2 skeletons per data-set without St. Helen-on-the-Walls, and 40.0% (2 of 5) have more than a hundred skeletons. With these revised figures it appears that the Central Southern region tends to have the larger skeletal samples, with a mean of 188.3 skeletons per data-set, a maximum of 384 skeletons in a data-set, and with 66.7% (2 of 3) having over a hundred skeletons. In comparison, the Eastern/Central Eastern region has 131.8 skeletons per data-set, a maximum of 250 skeletons in a data-set, and half have over a hundred skeletons.

7.11.3.1 Proportions of Adults and Subadults.

The Far North and Central Southern regions both approach the expected ratio of adults to subadults (70% adults and 30% subadults). Although the Far North contains five monastic sites, which might be expected to lower the proportion of subadults present, four of these (the three Carmelite Friaries and Jarrow B) have demonstrated a somewhat unusual distribution of subadults to adults. This region also contains the large cathedral site, which demonstrated a 'normal' ratio of adults to subadults, plus two church cemeteries. Only three sites represent the Central Southern region, including one church cemetery, one monastic cemetery, and one hospital cemetery. On balance the distribution should show a low proportion of subadults, but the church and monastic cemeteries both have an exceptionally high proportion of subadults, which has counterbalanced the low proportion present in the hospital sample. Both remaining regions, the North/North West and the Eastern/Central Eastern, have a low proportion of subadults and a high proportion of adults. The Eastern/Central Eastern region comprises two church data-sets, but both are small in comparison to the monastic and hospital (one of each) data-sets present. The North/North West also contains two church cemeteries, but although one of these is particularly large, there are three monastic data-sets, plus one hospital site, which together have lowered the proportion of subadults present.

7.11.3.2 Sex Distribution.

All the Late Medieval regions, excepting the South East region with no data-sets available, had significantly more males in the sample than normal, although the Far North sample, with 56.4% male skeletons, was only significant at the 2.5% level. This is probably because of the same reasons cited for the proportion of adults and subadults discussed above: this group contains the Carmelite and Benedictine monastic samples, both of which have shown a higher proportion of females than were present in the other monastic groups. The sex distribution remains skewed in favour of males in all regions, reflecting the distribution of church, monastic and hospital sites throughout the country.

7.11.3.3 Age Distribution.

7.11.3.3.1 Adults in General.

In contrast to the Early Medieval regions, where the majority had similar age distributions, the age distributions of most of the Late Medieval regions were significantly different from each other. The only two regions that were not significantly different were the North/North West and the Eastern/Central Eastern regions. The Far North was the only region with a higher proportion of adults in the two younger age groups, and it also had the lowest percentage of individuals in the Old Adult category. The Central Southern region had the largest proportion of individuals in the two older age categories, and also the most individuals in the Old Adult group. The Eastern/Central Eastern region had a substantial percentage of individuals in the Old Adult group, but also the highest proportion in the Young Adult category. Most of the adults in the North/North West region were distributed in the two middle age groups.

7.11.3.3.2 Adults Male and Female Subdivisions.

Again, none of the age distributions of the males and females were significantly different from each other, although some differences were present. In two regions, Far North and Eastern/Central Eastern, more males were placed in the two older age groups, but the situation was reversed for the other two regions. When the male age distributions were compared between regions, only two regions were significantly different from each other: North/North West and Central Southern. The Central Southern region had a high proportion of males in the Old Adult category, but also a higher percentage in the Young Adult category when compared to the North/North West group, although both had more individuals in the two older age groups than in the younger. In contrast, significant differences were found between the age distributions of the females of the Far North and North/North West, Far North and Central Southern, and Central Southern and North/North West. As with the adults, the Far North group was the only one to have a higher proportion of females in the two younger age groups, and it also had the lowest proportion of females in the Old Adult category. The North/North West region had the smallest percentage of females in the Young Adult age group, and the Central Southern region had the largest proportion of females in the Old Adult age category.

7.11.3.4 Caries Prevalence.

7.11.3.4.1 Teeth From Adults.

Freeth (1999) suggests that in the Late Medieval period geographical differences in caries prevalence were more dependent on access to new imported foods than to geoclimatic variables, and that the increased variety of foods would lead to social distinctions in diet. With an increase in trade the upper classes could afford to purchase food items, and so broaden the variety of their diet and perhaps introduce new methods of food preparation and consumption habits. In contrast, the lower classes would still be largely dependent on locally produced foods governed by the restrictions of climate and landscape. For this reason, less change will have occurred in their daily diet. However, fluctuations in climate occurred that did influence the success of subsistence farming. From the early fourteenth century the climate deteriorated, becoming increasingly unstable and unpredictable, with cooler, wetter weather, more storms, and a marked cold period in the mid sixteenth century (Bell and Walker, 1992; Fagan, 2000). The adverse weather damaged harvests, and a succession of difficult years could culminate in widespread famine invariably accompanied by epidemics of disease, as occurred in AD 1315-1318 when 10-15% of the population is believed to have died (Dyer, 1989, 1998; Reed, 1990). These climatic changes are much more likely to have had an impact on the poor, dependent on local food, than on the rich who had the means either to obtain food from elsewhere or to move to where food was available (Dyer, 1989, 1998). Reed (1990) has pointed out that a combination of climate, aspect and altitude will exert a profound influence on vegetation growth, and that for this reason climate deterioration may have had more of an impact in highland Britain.

As with the Early Medieval sample, the Far North region had one of the lowest caries prevalence rates (7.1%) of the Late Medieval regions, and it also was the only region to have a higher proportion of individuals in the two younger age groups, and the lowest proportion in the Old Adult group. This age distribution is one factor that might account for the lower caries prevalence. If this region was more adversely affected by the climatic deterioration from the early fourteenth century onwards, then this might have had a greater impact on subsistence than was experienced in the lowland areas of Britain. As in the Early Medieval period, oats would have been the staple cereal crop, consumed as oatcakes and porridge (Dyer, 1989), and the same questions can be raised concerning the cariogenicity of oats as were discussed in Section 7.11.1.4. Kerr *et al.* (1990) have commented that caries prevalence in the Late Medieval period was lower in Scottish populations than in English populations, but give no reasons why this might be so. However, the same trend regarding coastal and inland location of sites is observed in the Late Medieval period as was noted in the Early Medieval period; again, all but one of the sites are located on the coast. Given the likelihood for lower caries prevalence rates to be observed in coastal sites (see Section 7.10.1.4), this could well be an important factor in the lower caries prevalence observed here. However, the large inland trade in marine fish present in the Late Medieval period, and the fact that the coastal samples displayed higher caries prevalence than inland sites in this period, imply that this factor was no longer of such importance. However, Mays (1997) did find evidence that some coastal populations of the Late Medieval period were consuming more marine produce than inland populations. The Late Medieval period is complicated by the differences in prevalence rate observed between the different cemetery-type samples. However, even though five of the eight sites were monastic, and therefore might be expected to show a high caries prevalence (see Section 7.7.1.4), these five sites include the three Carmelite friaries and the Benedictine site of Jarrow B, both groups noted for their low caries prevalence in comparison to the monastic sites of other orders (see Section 7.9.1.4).

The North/North West region had the lowest caries prevalence (although it was not significantly different from that of the Far North region), despite having three monastic sites (one Augustinian, one Dominican and one Gilbertine) and a hospital site amongst the six data-sets that make up this sample. The presence of these sites could be expected to raise caries prevalence, but this sample also contains the poor church cemetery of St. Helen-on-the-Walls, York, which, since it is much larger than the other data-sets, has probably exerted a considerable influence in lowering the caries prevalence. The Central Southern region had the highest caries prevalence (14.1%), but then this sample contained the largest proportion of Old Adults and only one of the three samples was a church sample. The Eastern/Central Eastern region had a high prevalence rate of 9.8% (excluding Rivenhall), or 10.4% including Rivenhall. If Rivenhall is excluded then the sample only consists of one hospital and one monastic site, both of which might be expected to demonstrate high caries prevalence. In summary, the regional variation in the Late Medieval sample is complicated by the presence of different cemetery types. Even though three of the regions contain a combination of church, monastic and hospital samples, and the remaining region contains church, monastic and cathedral samples, the number of each cemetery type varies, as does the relative number of skeletons contributed by each.

7.11.3.4.2 Teeth from Adult Male and Female Subdivisions.

In contrast to the data for adult teeth, the Far North sample had the lowest caries prevalence for both sexes, both of which were significantly different from those of the other regions. The higher caries prevalence of the North/North West sample no doubt reflects the absence of St. Helen-on-the-Walls from the sample for male and female teeth. This was the only region not to show a significant difference in caries prevalence between the sexes. The caries prevalence for the male and female teeth in the Eastern/Central Eastern and Central Southern regions reflect the trends observed with the adult teeth. The possible reasons for a sex difference in caries prevalence in the Late Medieval period have been discussed previously (Section 7.6.1.4).

7.11.4 Caries Prevalence in Regions Chronological Variation.

In three of the four regions for which data were available for more than one period, the Late Medieval sample had a caries prevalence that was significantly higher than that of the Early Medieval sample. The only exception was the North/North West sample, where the prevalence rates were very similar between the two periods and the difference was not significant. The position of the prevalence rates of the Middle

Medieval period varied. In only one region (Eastern/Central Eastern) did the Middle Medieval prevalence rate lie between that of the Early and Late Medieval periods, and this was the region with the largest sample number in terms of both sites (7) and teeth (7685). For both other regions only one Middle Medieval site had contributed data, the reliability of one of which (Trowbridge in the Central Southern region) has been questioned (Section 7.6.1.4).

These data suggest that the trend towards a higher caries prevalence in the Late Medieval period occurred over much of the country, but the extent to which this reflects changes in diet for the general population rather than just for wealthier classes is unclear. The potential bias in the Late Medieval sample towards urban and monastic sites means it is likely that the higher proportion of individuals potentially consuming a high status diet has inflated the caries prevalence. The lack of a difference between the Early and Late Medieval North/North West sample might reflect the presence of a large sample from a church cemetery known to have served a poor parish (St. Helen-on-the-Walls) in the Late Medieval sample. This might suggest that the actual increase in caries prevalence from the Early to Late Medieval period among the general population is not as great as usually believed. Given the general small size of the Late Medieval church data-sets, their 'signal' has probably been 'drowned out' by the larger and more plentiful data-sets from monastic and hospital cemeteries.

8 Conclusions

> "First and foremost the investigator must satisfy himself that the data to be compared are truly compatible: that is, are the age classes and the diagnostic criteria the same in each; have prevalences been correctly calculated; and are the raw data given so that further calculations can be made? From what I know of the literature, it is more likely that the moon is made of green cheese than that all these requirements will be satisfied" (Waldron, 1994a: p90).

8.1 Introduction.

By necessity this study used data on skeletal remains that had been collected by other people. The original intention had been to investigate patterns of disease in general, so data on a variety of disease categories were collected from these reports along with data on age, sex and stature (the details are described in Chapter 5). It had been anticipated that there would be problems with this approach, but the extent of the difficulties involved only became apparent as work progressed. Partly because of the limitations encountered in the way that data had been recorded and presented in the skeletal reports, the original aims of the project had to be modified and the study of disease restricted to the category that provided the most consistent data – dental caries. The first section of this chapter summarises the conclusions drawn from the analysis of the caries prevalence data discussed in Chapter 7: first a summary of each section is given, followed by an overall conclusion. However, even the data for dental caries were deficient in many respects (see Section 7.3), and the type of data provided were inadequate to gain more than a general impression of trends and possible differences between groups. It will require the collection of far better data to determine whether these trends are real and to gain a deeper understanding of the possible causes of any differences (Hillson, 2001). The second part of this chapter is a response to the quality of data that were encountered in skeletal reports during the course of this study. The aim is to highlight some of the issues that arose, as problems cannot be addressed unless they are known. Finally, suggestions for further work are made.

8.2 Dental Caries in Medieval Britain: Conclusions

8.2.1 Chronological Division

The aim was to examine chronological changes in caries prevalence between subdivisions of the Medieval period, and compare prevalence between the sexes. Caries prevalence was expected to be low in the Early Medieval period, and higher in the Late Medieval period. The main findings are summarised in bullet points below:

- Caries prevalence was low in the Early Medieval period, and significantly higher in the Late Medieval period; the prevalence in the Middle Medieval period was significantly higher than both, but if an anomalous data-set was excluded from the results then caries prevalence was only slightly higher than that of the Early Medieval period. These results are consistent with previous studies and conform to expectations.

- There were no sex-differences in caries prevalence in the Early or Middle Medieval periods, but females had a significantly higher prevalence than males in the Late Medieval period.

- Caries prevalence in subdivisions of the Early Medieval period was generally low, with the exception of the Early-Middle Saxon group. The latter was unexpected, and remains unexplained.

- There were no sex-differences in caries prevalence in most Early Medieval sub-groups, with the exception of the Early-Middle Saxon group, where a higher caries prevalence was seen in the male teeth. This was the only group where males were under-represented in the sample.

- There was no difference in the caries prevalence of adult teeth between the two Middle Medieval sub-groups.

- There were no sex-differences in caries prevalence in the Late Saxon group, but the female teeth of the Early-Late Medieval group had a significantly higher prevalence than male teeth.

These results suggest that a diet of low cariogenicity, similar for both sexes, was consumed throughout the Early Medieval period, with the exception of the Early-Middle Saxon group. The slightly higher caries prevalence, and slightly increased (but not significant) caries prevalence in females compared to males observed in the Middle Medieval period might indicate the beginning of changes in diet that became more pronounced in the Late Medieval period. The data for the Late Medieval period suggest an increase in the cariogenicity of the diet, but since the sample consists of a large number of monastic and hospital sites, reflected in the demographic composition, it is questionable how much of this increase was experienced by the general population and how much relates to the presence of a considerable number of individuals who were consuming a more privileged diet.

8.2.2 Late Medieval Cemetery Types

The aim was to examine the relationship between status and caries prevalence in the Late Medieval period through a comparison of skeletal remains from different contexts, and to explore sex-differences in caries prevalence. The church and cathedral sites were expected to have a lower caries prevalence than the monastic and hospital sites. The main findings are summarised below:

- The church and cathedral samples both had an even number of males and females, and around 30% of the sample were subadults. In contrast, subadults and adult females were under-represented in the monastic and hospital samples.

- The caries prevalence of the church sample was significantly lower than those of the monastic and hospital samples, but also lower than that of the cathedral sample. This latter finding was unexpected.

- The caries prevalence of the hospital sample was significantly higher than all other cemetery types, including the monastic sample; again this was unexpected.

- The cathedral and monastic samples had a similar caries prevalence.

- There were no sex-differences in caries prevalence in the monastic sample; but in the hospital sample female teeth had a significantly higher prevalence rate than male teeth. Unfortunately there were no data on caries prevalence available for the cathedral sample, and what little data were available for the church sample seemed unreliable.

These results suggest that the general population buried in the parish churches was consuming a less-cariogenic diet than that of wealthier individuals and those following a religious life. However, important questions regarding status and differences in diet between the lay and monastic population cannot be answered due to the lack of data on precisely which individuals are included in the samples. The lack of data on sex-differences in caries prevalence in the church and cathedral samples does not help. Another possible reason might be urban/rural differences, but these were not investigated. The high caries prevalence in the hospital sample could also reflect the presence of wealthy individuals, or be linked to the inclusion of poor and/or sick individuals in the sample.

8.2.3 Non-Monastic and Monastic Sites: Chronological Variation

The aim was to compare non-monastic and monastic sites between the Early, Middle and Late Medieval periods in order to investigate secular and monastic changes through time. A greater change was expected in the monastic context. The main findings are summarised below:

- The increase in caries prevalence in the Late Medieval non-monastic sample was not as pronounced as that observed for the period overall, although it was still significant. In comparison, the increase in caries prevalence in the Late Medieval monastic sample is considerable.

- The monastic samples of the Early and Middle Medieval periods both have a significantly lower caries prevalence than that of the non-monastic samples of the same period, whilst the monastic sample of the Late Medieval period has a caries prevalence significantly higher than the Late Medieval church sample.

- There were no sex-differences in caries prevalence in the monastic samples in any period, nor were there were sex-differences in caries prevalence in the non-monastic samples of the Early and Middle Medieval periods. Data for the Late Medieval period appear unreliable.

These results imply a general similarity of diet for the general population between all three periods, with the slight increase in caries prevalence in the Late Medieval period possibly due to changes in the processing of carbohydrates (for example, consumption of less-coarse bread), or consumption of less cariogenic foods, rather than a considerable increase in the intake of cariogenic foods such as sugars. This would be consistent with what is known of the diet of the general population of these periods. However, it could be related to the higher proportion of older adults in the Late Medieval sample compared to the earlier periods. The low caries prevalence in the early monastic samples could imply adherence to the strict dietary Rules of the early monasteries, but the extremely low caries prevalence in the female teeth cannot be explained in this manner. However, the samples for both periods are small. The large increase in caries prevalence in the Late Medieval monastic sample may well indicate that the largest change in diet occurred among the wealthier individuals, who gained access to imported luxury foods such as dried fruits and sugars. It could also suggest a relaxation of dietary Rules.

8.2.4 Late Medieval Monastic Orders

The aim was to explore any differences between the various monastic orders. The main findings are summarised below:

- Two groups with different demographic profiles emerged. The Augustinian, Dominican and Gilbertine samples all consisted predominantly of adult males, as might be expected from a monastic sample. In contrast, the Benedictine and Carmelite samples both had a high proportion of subadults (compared to both church and other monastic samples), and an equal number of males and females. These trends were most pronounced in the Carmelite sample, where a high proportion of the adults were also young.

- The caries prevalence in the Augustinian, Dominican and Gilbertine samples was high, especially in the Gilbertine sample, but in the Benedictine and Carmelite samples caries prevalence was low.

- Female teeth had a higher caries prevalence than male teeth in the Dominican, Gilbertine, Benedictine and Carmelite samples, but male teeth had a higher caries prevalence than female teeth in the Augustinian sample.

Interpretation is difficult due to the lack of data on which groups of individuals are present in each sample. The demographic data for the Benedictine and Carmelite samples suggest that these might represent a different group of individuals to those present in the other monastic samples. In turn this might be related to the differences in caries prevalence observed. Unfortunately, the poor data from the church sample cannot act as a useful comparison.

8.2.5 Location: Coastal and Inland

The aim was to compare caries prevalence between coastal and inland sites in the Early, Middle and Late Medieval periods. The Early Medieval coastal sites were expected to have a lower caries prevalence to those inland, but the difference was expected to disappear in the Middle and Late Medieval periods. The main findings are summarised below:

- Caries prevalence in the Early Medieval coastal sites was significantly lower than that of the inland sites. There were no sex-differences in caries prevalence for either group.

- There were no differences in the caries prevalence of the adult or female teeth between coastal and inland Middle Medieval sites. However, inland males had a lower caries prevalence than coastal males. A higher caries prevalence was seen in costal males compared to coastal females, but inland males had a lower caries prevalence than inland females.

- The results for the Late Medieval sample are conflicting, in that the adult coastal teeth show a higher caries prevalence than the inland sample, but the male and female teeth show the opposite trend.

- The same overall trend of a caries increment from the Early to the Late Medieval periods was observed in both inland and coastal samples, but the increase was greater in the coastal sample.

The low caries prevalence in the Early Medieval coastal sample could indicate a higher consumption of fluoride-rich marine fish in these areas. The results for the Middle Medieval samples might reflect the beginning of large-scale deep-sea fishing and the trade of marine fish inland, but sample sizes are small. By the Late Medieval period marine fish were certainly being caught on a large-scale, and were being traded far inland, so if marine fish was exerting a protective effect against dental caries then there should no longer be a difference between inland and coastal samples. It is possible that the different Late Medieval context types are confusing the issue. Additionally the relationship between other dietary and behavioural factors is unknown. Without stable isotope analysis the marine component of the diet cannot be directly addressed with any certainty.

8.2.6 Regional Variation

The aim was to explore any regional trends in caries prevalence within and between the three main periods. The main findings are summarised below:

- Caries prevalence was low in all Early Medieval regions, especially the Far North and Eastern/ Central-Eastern groups. No sex-differences in caries prevalence were observed in any region.

- Apparent regional differences in the Early Medieval period may be due to variation in the number of coastal and inland sites in each regional sample. The exception was the Eastern/ Central-Eastern group, where the low caries prevalence may in part be related to the location of sites near the Fens, and possibly a consequent higher inclusion of animal products and fish in the diet.

- The examination of regional trends in the Middle Medieval period was hampered by a lack of data for most regions.

- The pattern of regional variation in the Late Medieval period is complicated by the presence of different cemetery types.

- In three regions the Late Medieval caries prevalence is higher than that of the Early Medieval sample, but in one region there was no difference in caries prevalence between Early and Late Medieval periods.

8.2.7 Conclusions

Overall, the results suggest that the increase in caries prevalence in the Late Medieval period was mainly experienced by the wealthier individuals and/or those in a religious order. It appears that the diet of the general population did not change drastically from that of the preceding periods, although some increase in cariogenicity might have been generated through changes towards consumption of more-refined carbohydrates. The general trend for skeletal samples from church sites to be much smaller than those from monastic sites, as well as the lower number of church sites in the sample overall, seems to have resulted in an under-representation of the general population in the Late Medieval period, thus providing an artificially high impression of the caries experience of the Late Medieval population. Better data from the church cemeteries would also help investigate sex differences in caries prevalence in the general population, which would assist interpretation of the sex differences (or lack of them) observed in the hospital and monastic sites. A lack of rural sites has also been noted in the Late Medieval period, and it is likely that the large number of urban sites in the sample is influencing caries prevalence. Trends in caries prevalence related to the coastal versus inland location of sites have also been tentatively identified, but whether these are related to the marine content of the diet is unclear. The use of stable isotope analysis might help resolve this question. In all cases the trends identified in this research are speculative, as the reliability of the data is questionable and the data on age-at-death in relation to caries prevalence cannot be taken at face value. Some of these apparent trends may be spurious, and all require investigation with better data.

8.3 Skeletal Reports in Modern Britain: Conclusions

8.3.1 Finding Skeletal Reports.

The availability of published and unpublished skeletal reports was an important factor in determining whether the data they reported could be included in the present study. Finding skeletal reports could be difficult, however. If they had been published, the place of publication could vary from a monograph, to a chapter or appendix in a site report, to an article in a journal (often a local archaeological or historical journal). Unpublished reports could be even harder to locate and necessitated trips to archives, or depended on the kindness of individuals to provide copies of their data. At the time this study began there was no source generally available that gave specific information regarding the skeletal reports in existence, where to find them or how to access them, and locating suitable skeletal reports or collections has often been regarded as a major (and time consuming) undertaking (Roberts and Cox, 2003). This state of affairs is particularly daunting for the majority of Masters and PhD students who lack the accumulated knowledge of more experienced researchers and who may find it hard to know where to begin. The problem of locating skeletal reports was encountered by Roberts and Cox (2003) during the course of their study, and their book has gone a long way towards addressing the issue through providing a list of all the sites used from each period together with a reference to the published/unpublished sources. An early version of this list (available prior to publication) was of enormous help to the present author in the process of tracking down reports.

Helpful though it is, the problem with a published list is that it remains static and cannot be easily updated as new sites are discovered, and the amount of information it is possible to include is limited. A solution recommended by Roberts and Cox (2003) entails construction of a centralised database that, as well as data relating to the site itself and an overview of the skeletal collection, would include electronic access to unpublished reports and an archive of the original data collected for each skeleton. Such a database would be invaluable to anyone intending to conduct research on skeletal populations in Britain and would encourage work to take place on a much broader selection of skeletal material, rather than repeatedly focussing on those collections that are well known and would also justify retention of skeletal remains in museums. Through incorporating other archaeological environmental and cultural data it would enable the evidence preserved in human remains to be explored to the maximum, making it easier to employ a biocultural approach.

Ideally, such a database would become integral to the recording and analysis of skeletal material from a site, thus encouraging people to use it. Computer-based recording forms have already been developed by Brian Connell and are being used to record the many thousands of skeletons excavated from Spitalfields Market, London (Redfern, 2004). The European Health Project is also currently using a standard electronic recording form, which is downloaded and used to record the data for each skeleton straight onto the computer, rather than the more traditional paper recording forms used by the majority of osteologists working in Britain today; paper copies of the data can be printed if required (Global History of Health Project, 2002). The data collected in this way can then be uploaded straight into the main database, thus eliminating the extra effort involved in separate data entry. Functions within the database calculate the relevant figures, for example the number of individuals, or the number of each bone element present in the sample, or the number of cases of a particular pathological lesion. This functionality allows prevalence rates to be calculated quickly and easily for both individuals and bone/tooth elements, which facilitates analysis of the data. The use of such a database by osteologists as a matter of course would make the writing of skeletal reports easier, and would encourage all data collected from skeletal remains in Britain to be reported to a consistent standard and format, thus addressing many of the other problems encountered in skeletal reports, which will be discussed in more detail below. There could be restrictions in place to prevent the data gathered from a skeletal collection from being available to everyone until the skeletal report had been written and made available (either published or as an electronic unpublished report).

8.3.2 Data Quality.

Even once the skeletal reports had been located, collecting comparable data from them proved somewhat of a challenge. Few reports included relevant information about the site from which the skeletons were excavated and several launched straight into the analysis of the material without placing it in context. In one instance the report embarked upon an analysis of the pathological conditions without even presenting data on the demography of the population under study! If the report was published as part of a site report then data on the site itself could usually be found in the rest of the report, although sometimes the information that was of particular interest was not discussed, was not made explicit, or was difficult to extract. For example, on one occasion the only mention of the dates of the cemetery in question was tracked down in an obscure passage on microfiche when it would be expected that such an important piece of information would be included in the main text. A considerable number of site reports neglected to provide details on the location of the site in question, meaning that grid references had to be obtained from other sources (see Section 5.3), thus introducing another possible source of error. If the skeletal report was unpublished then the lack of even the most basic data on the site in the report itself was particularly problematic. In several cases skeletal populations have had to be used in this study where there was minimal data on the context of the sample. This situation does not help the integration of biological data with other archaeological evidence.

Problems arose with converting the often subjective and inconsistent presentation of data that occurred within and between reports into the defined categories and explicit numbers required by the computer. It was impossible to define fields within the database that would enable comparable data to be collected from all reports. For these reasons the evidence for disease was recorded at the most basic level, and even then not all sites were able to contribute valid data for entry into the computer. These problems were exacerbated by the presence of numerical discrepancies in the text, tables, figures, and skeletal catalogues, which had to be resolved before computer input. This process required the author to make decisions based solely on the textual information available, and will have introduced another layer of error to the data. In the case of some sites it was felt that the data for a particular disease conflicted to such an extent that any decision would be completely arbitrary, and so it was not recorded.

The condition of the skeletal remains is important, as it will affect the likelihood of being able to age and sex the individuals and the probability that evidence for pathological conditions will survive to be observed (Walker, 1995; Waldron, 1987b). In addition, the ability to diagnose diseases differentially is influenced by the state of the material (Waldron, 1987b). Janaway *et al.* (2001) have previously criticised the inadequate recording of the condition of human remains, and the present study confirmed this view, finding that the preservation and completeness of the skeletons was often not mentioned in the skeletal reports, and when it was it was usually not discussed in any detail. A subjective statement was common, with no definition of what was meant by 'well' or 'poorly' preserved. Some reports provided tables showing the number of skeletons in different categories, but again definition of these was lacking. In a few cases information on preservation was provided, but with no information on the degree of completeness. The information given was noted, but due to the complete lack of definitions, absence of common standards and wide variance in presentation it was impossible to translate this into a measure comparable between sites.

Simply establishing the number of skeletons that were recovered from the site often proved astonishingly difficult. It is recognised that it is not always easy to determine the number of individuals that were present, but some decision must have been reached by the osteologist recording the data and this should be clearly stated. If it is not then it is difficult for the person reading the report, without access to the original skeletal sample, to know how many skeletons there were when confronted with statements such as the following:

> "The possible range of numbers present in this group is wide, and the actual numbers almost impossible to determine... the minimum number of individuals of all ages is forty-four. This is based on those individuals who are fairly complete. The total suggested by a count of individuals both fragmented and complete, and based on actual numbers allotted to skeletons, is about 170. The inventory of skeletal material from the excavation itself suggests a minimum of about ninety. The reality is probably about 130 individuals. Whatever the exact number, the sample is sufficiently large, given the nature of the evidence, for some useful conclusions to be drawn" (Stirland, 1985: p49).

It could be even more difficult to resolve the numbers of individuals in the different age and sex categories. If tables were given, invariably the numbers given in the table categories did not add up to the total given at the bottom of the table. This in turn may not have matched the numbers given in the text. The number of individuals in the tables for sex often did not correspond with the number of individuals in the tables for age, and sometimes neither bore any relation to the total number of individuals said to be present in the collection as a whole. The number of skeletons listed in the skeletal catalogue (if one was provided) often differed yet again. The scale of the discrepancies varied from quite small and probably typographical, such as 134 individuals in the text but 133 individuals in the table, and those that were relatively easily resolved, to those that were virtually impossible to disentangle. On numerous occasions the data on demography had to be collated from the skeletal catalogue just to ensure that there was agreement between the numbers of individuals in different age and sex categories. Several reports had sexed subadults, and included them in the total with the adult males and females. In discussion it often appeared as though the fact that subadults were present in these total numbers of males and females had been forgotten and the total males and females were referred to as adults throughout the report.

The age of an individual can influence their experience of disease. For example, osteoarthritis increases in frequency with age, so, all else being equal, a sample consisting predominantly of young individuals will display a lower frequency of osteoarthritis than a sample where older individuals predominate (Aufderheide and Rodríguez-Martín, 1998). Information on the age composition of the sample is therefore important, but problems with the comparison of age-at-death distributions between samples had been foreseen as a problem. At the most basic level this involves the difficulty in achieving accurate age-at-death estimations for adult skeletons and the unreliability of many of the ageing methods used (Molleson, 1995; Key, *et al.*, 1994; Murray and Murray, 1991; Powers, 1962). In addition, many of these ageing methods have not been developed until comparatively recently and would have been unavailable at the time most of the reports were written. To compound the problem, the presentation of the age-at-death data differed between reports. The age at which adults and subadults were divided was found to range between 15 and 25 years, although the majority used 18 years of age to denote adulthood (see Section 6.2). Further problems involved the extremely varied age categories into which the skeletons were divided in different reports (see Table 5.3:1), which had to be standardised in order to combine and compare data from different samples as achieving any kind of direct comparison between sites was deemed impossible. This process will have increased the degree of error present in the data. It was also difficult to relate the data on age-at-death to the data on pathological conditions.

Stature can be influenced by environmental factors and so be a general indicator of health (Roberts and Manchester, 1995). Most reports provided some kind of data on stature, but again problems of consistency emerged. Fortunately, almost every single report where the methodology had been given had used a version of the formulae of Trotter and Gleser (1952; 1958; Trotter, 1970), and only two sites had used a different formula. One of the latter was published in 1923, well before Trotter and Gleser's formulae were developed. Even though the same formulae were used for the majority of sites, the methods of applying them sometimes varied. Although Trotter and Gleser state explicitly that averages of stature estimates from several long bones from each skeleton should not be taken, several reports described doing just that. On more than one occasion stature estimates for unsexed adults were encountered, even though the formulae for stature calculation are sex-specific. Not all reports had given data on the mean stature for males and females, or given the range for each sex. Often they omitted to give the number of individuals for whom stature could be calculated. In the instances where stature data were deficient, the stature given for each individual in the skeletal catalogue had to be collected in order to calculate the mean and the range.

The data on the diseases themselves were also found to vary considerably between skeletal reports. Firstly, not all osteologists had recorded the same diseases for each sample. Also diseases may be placed in different categories in different reports, for example several of the congenital conditions were often found discussed under non-metric traits. Secondly, the methods used to present the data on disease varied enormously. Few reports had included data on the number of elements affected together with the number of elements present, so that absolute prevalence rates could be calculated. In most cases the only data that could be obtained related to the number of individuals affected, which does not take account of the fact that most skeletons are incomplete due to postmortem damage (Roberts and Manchester, 1995; Waldron, 1991, 1994a). However, even simply recording the number of individuals present with a certain condition could prove extremely problematic due to idiosyncrasies in the way those data were presented. Frequently, vague and generalised comments were made regarding the occurrence of a particular disease, without any summary of the relevant data being provided. Reports did not always state the number of males and females with a given condition, making it hard to compare the prevalence of diseases between the sexes. Often the more common conditions, such as osteoarthritis, were not reported to a satisfactory standard while attention was focused on those diseases perceived to be more interesting because of their comparative rarity. This ignores the fact that the more common diseases have the potential to reveal a great deal about the life of the population concerned.

As with the data on numbers of individuals in each age and sex group and in total, the data on disease were equally prone to discrepancies. Numbers in tables did not necessarily add up to numbers given in the text. Sometimes a skeleton with a certain condition was listed as being male, but in the skeletal catalogue the sex of the same skeleton was given as female. If prevalence rates were calculated it was not always clear exactly which numbers had been used as the basis of the calculation: on one occasion the number of skeletons with DISH was given as zero, but the prevalence was given as 6%. In instances such as these it is difficult to know which is the correct figure. Frequently the skeletal catalogue was turned to for clarification, but it soon emerged that in many cases the catalogue contained skeletons with certain pathological conditions that were not included in the numbers and discussion of that condition in the main report, or that when the text of the report referred to a particular individual as having a certain condition this was not always given in the catalogue entry for that skeleton. The quality of data contained in the catalogue could leave much to be desired. Ambiguous comments could be encountered, the meaning of which was obscure. For example, in one catalogue the entry for one particular skeleton included the comment "teeth impossible"; in another, where much effort was lavished on recording the presence of wormian bones in great detail, a single column was devoted to all remaining pathological conditions, and the entry for one skeleton read: "Nearly all postcranial bones abnormal" without any further elaboration. Having to collate data from the skeletal catalogue is time consuming, and the success rate is dependent on the type of data included in the catalogue, the way in which they are presented, and the degree of consistency present throughout the catalogue. However, at least if a catalogue is included then the data are available to others, which is better than no data being available at all.

In comparison to the data on most other disease categories the data on dental caries tended to be much better, as many skeletal reports had included the number of teeth present and number of teeth affected by dental caries. For these sites it was possible to calculate the actual prevalence of dental caries as teeth affected divided by teeth present. However, not all sites managed to present useful data on dental caries, and the limitations of the caries data available have been discussed in more detail in Chapter 7.

8.3.3 Trends in Excavation and Publication.

The dates that the skeletal remains had been excavated ranged from the early 1920s through to the late 1990s, but two thirds (58) of the 88 data-sets had been excavated in the 1970s or 1980s (see Table 8.3:1). In contrast, the majority of the published data-sets (41, 62.1%) had been published relatively recently, in the 1990s (see Table 8.3:2). Although these numbers might be biased, in that it was probably easier to find and get hold of the more recent publications, it seems reasonably likely that this does reflect the true situation in Britain. Many sites were excavated during the 'rescue archaeology' phase in the 1970s and early 1980s as the impact of modern development increased, with little or no financial provision for post-excavation work or publication (Thomas, 1993; Hunter, *et al.*, 1993). Recent funding has been directed towards clearing this backlog of unpublished sites, with the result that many sites have finally been published in the last decade (Thomas, 1993).

None of the Late Medieval data-sets, and only one of the Middle Medieval data-sets, had been excavated prior to the 1970s, whereas nearly a third of the Early Medieval data-sets had been excavated before this date. A higher proportion of the Early Medieval data-sets had been published (36, 87.8%) compared to the Middle Medieval (10, 76.9%) or Late Medieval (20, 58.8%) data-sets. Most Early Medieval data-sets were published in the 1990s (26, 72.2%), and considering that a fair number of them were excavated in the 1970s and earlier, it seems as though their publication has benefited from the recent impetus to publish those sites that had languished unpublished due to lack of resources. The fact that fewer of the Late Medieval data-sets have been published may partly be related to the fact that, in general, they have been excavated more recently; perhaps there has not been enough time yet for the sites excavated during the 1990s to complete the process of publication.

Table 8.3:1 Number of data-sets excavated in each decade.

Decade Excavated	Number of Data-sets (% of Total)							
	Early Medieval		Middle Medieval		Late Medieval		All Periods	
1920s	1	2.4%	0	0.0%	0	0.0%	1	1.1%
…								
1950s	7	17.1%	1	7.7%	0	0.0%	8	9.1%
1960s	4	9.8%	0	0.0%	0	0.0%	4	4.5%
1970s	10	24.4%	7	53.8%	12	35.3%	29	33.0%
1980s	13	31.7%	4	30.8%	12	35.3%	29	33.0%
1990s	5	12.2%	1	7.7%	6	17.6%	12	13.6%
?	1	2.4%	0	0.0%	4	11.8%	5	5.7%
Total:	**41**		**13**		**34**		**88**	

Table 8.3:2 Number of data-sets published in each decade (published data-sets only).

Decade Published	Number of Data-sets (% of Total)							
	Early Medieval		Middle Medieval		Late Medieval		All Periods	
1920s	1	2.8%	0	0.0%	0	0.0%	1	1.5%
…								
1950s	1	2.8%	0	0.0%	0	0.0%	1	1.5%
1960s	1	2.8%	1	10.0%	0	0.0%	2	3.0%
1970s	2	5.6%	0	0.0%	0	0.0%	2	3.0%
1980s	4	11.1%	4	40.0%	10	50.0%	18	27.3%
1990s	26	72.2%	5	50.0%	10	50.0%	41	62.1%
2000s	1	2.8%	0	0.0%	0	0.0%	1	1.5%
Total:	**36**		**10**		**20**		**66**	

There are implications to this delay between excavation and publication. In many cases there is no indication as to when the skeletal report was written, although it often seems to have been prepared not long after the site was excavated. Knowing when a report was written is important, as methods of recording and analysis have developed considerably during the 1980s and 1990s and the methodology available at the time of writing, together with contemporary research interests, would have affected the type of data recorded, how they were recorded, and how they were presented. There have been reviews of the methods employed in sexing skeletal material (Meindl, *et al.*, 1985a; Milne, 1990), the development and improvement of ageing methods (Meindl, *et al.*, 1985b; Lovejoy, *et al.*, 1985; İşcan and Loth, 1986; Loth and İşcan, 1989; Walker, *et al.*, 1991; Buckberry and Chamberlain, 2002), and tests of the accuracy and reliability of these methods (Murray and Murray, 1991; Molleson and Cox, 1993; Key, *et al.*, 1994; Molleson, 1995; Walker, 1995). For aging, in particular, it seems as though the degree of error is particularly high, with many methods under-aging old individuals and over-aging young individuals. The move towards standardised recording developed in North America in the 1990s as a response to issues raised by the reburial of large collections of Native American skeletal remains (Walker, 2000). In 1994, this resulted in the publication of *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker), which since then has acted as a guide for the data that should be recorded and how this should be achieved. Britain has lagged ten years behind North America, but this year (2004) has seen the publication of the British equivalent by the British Association of Biological Anthropology and Osteoarchaeology (Brickley and McKinley, 2004). This publication addresses issues of recording and analysis from a British perspective, where, unlike North America, the reburial of skeletal collections is not the normal procedure. However, this situation might change as a result of the recent developments concerning the possible reburial of skeletal remains in this country (Steele, 2004).

Methods of recording pathological lesions have also improved, emphasising the need for thorough description and differential diagnosis (Ortner, 1991, 1994; Lovell, 2000). Publication of scoring systems, where descriptions and photographs define the degree of severity of a particular lesion, for example Stuart-Macadam's system for scoring cribra orbitalia (1991), have helped to ensure some degree of consistency of diagnosis between individuals. Some pathological conditions found in skeletal remains have been recognised relatively recently, for example the criteria used to differentially diagnose Diffuse Idiopathic Skeletal Hyperostosis (DISH) from ankylosing spondylitis in skeletal material were not defined until 1981 (Rogers, *et al.*); following this more cases of DISH started to be recorded. Volumes containing comprehensive information on a wide range of pathological conditions have been published (for example, Ortner, 2003; Roberts and Manchester, 1995; Aufderheide and Rodríguez-Martín, 1998), which have assisted the process of identification and differential diagnosis of pathological conditions in skeletal remains. Even so, concerns have been raised about the accuracy of many diagnoses, and Miller *et al.* (1996) have reported that people are more successful at assigning a pathological lesion to a general disease category rather than attempting a specific diagnosis. This finding reinforces the necessity for adequate descriptions to be given in the report.

In addition, more consideration has been given to what the diseases diagnosed from skeletal remains actually tell us about the health of the population concerned. Wood *et al.* (1992) have exposed the problems with the assumption often made in palaeopathology "that direct relationships exist between statistics calculated from archaeological skeletal series (e.g. skeletal lesion frequencies and mean age at death) and the health status of the past populations that gave rise to the series" (1992: p343). The sample of the population available for study consists of those individuals who died in each age group, perhaps as a result of disease. They are therefore the "non-survivors", those who did not have the ability to withstand ill health. This implies that the prevalence of disease in skeletal material will be an overestimate of that experienced by the living population. However, this does not take account of the fact that the skeleton is a relatively insensitive indicator of disease, and therefore the evidence from skeletal material also underestimates the true pattern of disease in the living population. Wood *et al.* observe that it is probably impossible to determine the degree of under- and overestimation of disease that is present in the data gathered from a skeletal sample, and so it will always be impossible to gain a reliable estimate of disease prevalence in skeletal populations.

Wood *et al.* (1992) also consider the implications of the nature of the skeletal response to disease. Since a certain amount of time is required for bone to produce the changes that show evidence of the disease process, any acute diseases, where the patient either recovers or dies within a short space of time, will not leave any evidence in the skeleton. Chronic diseases, where the patient survives with the condition for a lengthy period of time before either death or recovery, are much more likely to result in bony changes. The paradoxical situation that results is that those individuals with a strong immune response will quickly tend to fight off any episodes of acute disease, leaving no trace of their experience in their skeletons. Likewise, those individuals with a weak immune response are more likely to succumb to disease quickly, again leaving no trace of the process in their skeletons. Since neither group of individuals have produced any bone changes, both groups will appear the same to the osteologist that examines them, and the lack of disease evidence will probably be interpreted to mean that both groups were healthy when in reality one group was not. In contrast, when individuals with a reasonably healthy immune response experience an episode of disease, whilst they may not be able to fight off the disease completely, they are capable of surviving with that disease for a time before they recover or die. They may show evidence of this process in changes to their skeletons and therefore appear unhealthy to the osteologist that examines them, whereas they were actually healthier than the group with weak immune systems that displayed no evidence of bone changes.

8.3.4 Accuracy and Comparability.

These refinements of methodology and theory have helped progress the field of palaeopathology, but for any research to make use of the data presented in skeletal reports, for whatever purpose, the issues of accuracy, reliability and comparability are paramount (Ortner, 1991; Waldron, 1994a). These are just as essential to every stage of the process of analysing skeletal material, from the actual recording of the data to the presentation of the results. There will always be a certain degree of both intra- and inter-observer error when skeletal material is recorded, and recommendations have been made to determine the extent of the error present and to try and ensure that some degree of consistency is maintained in what is being recorded (Brickley and McKinley, 2004; Buikstra and Ubelaker, 1994). Obviously, much of the data collected from skeletal samples over the last few decades have been recorded by multiple individuals with varying degrees of experience and/or training, and until recently there have been no commonly agreed standards as to what should be recorded and how (Brickley and McKinley, 2004; Buikstra and Ubelaker, 1994). The introduction and proliferation of specialised courses teaching physical anthropology during the 1980s and 1990s has ensured that there are now people with the relevant qualifications working in the field, who should, in theory, be recording data to a high standard (Roberts and Cox, 2003). It is not surprising that in past skeletal reports the categories of diseases recorded have varied, along with the methods used to record them. For example, the criteria for diagnosing osteoarthritis have been defined by Rogers and Waldron (1995), but from the descriptions of what was being recorded as 'osteoarthritis' in many of the skeletal reports encountered in this research it was clear that different criteria were being employed. In particular, when recording osteoarthritis in the vertebrae it was clear that some individuals had only included the apophyseal and costal synovial joints, whereas others had included the surfaces of the vertebral bodies. Variable terminology has also confused the issue: for example, osteoarthritis can also be referred to as arthritis, degenerative joint disease, arthritis deformans/deforming arthropathy (Aufderheide and Rodríguez-Martín, 1998).

This issue of the lack of consistency in data recording is compounded by the fact that the data collected are not presented in a consistent fashion. Ortner (1991: p10) has complained of the quality of data available from skeletal collections and discussed the implications, observing that "perhaps the most serious problem is the current inability to use most of the data on paleopathology found in published sources for comparative research". Roberts and Manchester (1995: p105) have stated clearly the need for consistency in recording: "The basic point to make is that, as with any palaeopathological lesion, recording the basic data in a standardized format is essential so that comparisons can be made". Waldron (1994a) has also emphasised the importance of consistent recording and rather colourfully expresses his view that such standards are not currently met in the majority of the literature in the quote at the beginning of this chapter.

The recurring theme is that comparison of disease prevalence rates between populations is essential for the progression of palaeopathology, and in order for the comparison to be meaningful it must be ensured that like is being compared with like. Yet, whenever studies have been attempted that pull together data from published sources, the same complaint is met. Rose *et al.* (1991) found that the data available in the published and unpublished sources they incorporated into their study were variable, and that this affected their sample sizes. Littleton and Frohlich (1993) encountered difficulty comparing published data collected by a variety of researchers due to the varying presentation of results. Saunders *et al.* (1997: p72) comment on the difficulties of using other published material for comparison due to "variations in the reporting of data". Steckel and Rose (2002a: p xi) observed that in the past "physical anthropologists often devised their own, sometimes idiosyncratic reporting schemes, which hindered true comparability of results across time, space, and ethnic groups". Freeth (1999) also complains of the impossibility of using previous research for comparison because of the way the data were presented, citing variations in the way caries data were calculated, lack of provision of the raw data, descriptive comments, and the problems of extracting real numbers when data are presented as figures without tables. Roberts and Cox (2003: p399) when compiling data from skeletal reports in Britain, like the present author, "encountered ambiguous phrasing, and terminology that was, to the expert and non-expert alike, confusing and unintelligible". They also noted problems incorporating the data on age-at-death with the data on pathological conditions, variation in which diseases were recorded, and a focus on the more unusual diseases rather than the common. In addition, they found it difficult to establish prevalence rates for certain conditions, such as osteoarthritis, as few reports gave data on the numbers of bone or tooth elements, or joints, present. On occasion "the level of data quality in some reports [was] so poor that they could not usefully be included" (Roberts and Cox, 2003: p27).

Only one or two skeletal reports were found that had no errors or discrepancies in numbers at all during the course of this study. Therefore, in the vast majority of reports at least one error was present, or there were inconsistencies in the data given throughout the report. Sometimes these discrepancies occurred frequently within a report, or were on a particularly large scale. Human error will always be a factor, and a few errors creep in no matter how thoroughly things are checked, but the scale of many of the discrepancies observed in many published (and unpublished) reports implied that adequate checking was not carried out. It is essential that these errors be kept to a minimum. This issue of accuracy is a serious one. One function of a skeletal report is to report the basic data retrieved from a population in order to disseminate that information to as many people who may be interested (Mays, 2004). It is important that the data presented in these reports are accurate; there are enough issues at present with the problems of defining diagnostic criteria, and dealing with inter-observer error and differences in diagnosis between individuals, without having to contend with poorly presented data as well. Where skeletal collections have been reburied (or will be reburied at some point in the future) the remains themselves can never be re-studied and the skeletal report forms the primary source of data on that sample. Thankfully, it is not normal practice in Britain yet for skeletal collections to be reburied, at the moment at least, but the issue does arise, for example with remains excavated from church cemeteries still in use (Mays, 2004), or with cemeteries belonging to specific religious groups such as Jews (Lilley, *et al.*, 1994). Even if the skeletal remains are not reburied, it is still the responsibility of the osteologist recording the sample to make sure that they employ appropriate recording methods, that they adhere to standards of data recording that have been set and that the data they record are accurate (Brickley and McKinley, 2004; Buikstra and Ubelaker, 1994).

The quality and extent of recording and analysis of human remains from archaeological sites has frequently suffered through lack of adequate resources and many of the problems that were noted with the skeletal reports are very likely a product of the conditions under which the data were collected and the report was written. Archaeology is under-resourced, and since the implementation of PPG 16 and the 'polluter pays' principle archaeological units have had to compete with each other for work (Hunter, *et al.*, 1993; Thomas, 1993). The developers naturally tend to choose the unit offering to do the work for the least cost, and so pressure is placed on all to complete the job in the minimum time available with minimal resources. This climate has undoubtedly affected the standard to which human remains are recorded;

where it becomes impractical to record full sets of data for each skeleton choices are made as to what areas will be recorded, and corners are cut (Roberts and Cox, 2003).

Recording the raw data is not the only area that demands care and attention. There is little point recording an accurate and thorough set of data for a skeletal sample if those data are poorly presented; equal thought must be given to the presentation of data in the skeletal report. The advice given in the BABAO Standards (Brickley and McKinley, 2004) is mainly directed towards recording the material, with less attention given to its presentation. Although presentation is discussed and recommendations made (for example, Roberts and Connell, 2004), the general assumption seems to be that if material is recorded to a specified standard then the data will automatically be presented in an acceptable format. However, a perusal of extant skeletal reports suggests that presentation of data is an area that could do with improvement. This is a fact noted by Freeth (1999), who stresses the importance not only of standardised diagnostic criteria and recording methods, but also the desirability of a standardised presentation format. Lukacs (1995: p152) also comments on the matter, specifically in relation to dental disease, observing that "although methodological papers attempting to standardize scoring of dental pathological lesions are common, few are concerned with inconsistencies in how dental pathology data are reported, and the consequent implications for comparative research". Lukacs made some strong recommendations for the presentation of data on dental caries, including clear presentation of data in four different ways: by observed tooth count, by corrected tooth count, by individual count, and as the mean number of caries per individual. However, the validity of applying a caries correction factor is questionable, and few researchers quote caries as the mean number of carious teeth per individual.

Basic requirements for the presentation of data should include the following factors. The methods used to record the data should be stated and care must be taken that the data are presented in a manner consistent with current recommended standards in order that data from different sites can be compared with each other in the future. Tables should provide a clear summary of the number of individuals present as a whole, and in each standard age and sex group. Tables on disease prevalence should include the raw data for number of individuals and bone/tooth elements affected, and the number of individuals and bone/tooth elements that could be observed. The numbers given in these tables should be thoroughly checked and cross-referenced with each other, and any discrepancies resolved. After all, the data forms the basis on which conclusions about the health status of that population are drawn, and inaccurate data will lead to the wrong conclusions. If there is a reason why certain individuals or bone elements have been excluded from a table then the number of individuals or bone elements excluded, and why, should be stated clearly so that this does not give rise to confusion later on. If a skeletal catalogue is to be included, then the data contained in it must be consistent with the summary data given in the report, as discrepancies will only serve to perplex those that attempt to study the data in the future. It is the osteologist writing the report that is best placed to do all this. It is they who have recorded the skeletal material, and who have made decisions about which skeletons should be included in which categories. It is their responsibility to ensure that the full potential of their data on the skeletal collection for future research is realised. In reality, most researchers in the field do not have the time/resources to collect all data themselves for every research project. Therefore, they have to rely on published data to achieve their research goal.

The importance of moving towards a population-based comparative approach has been discussed (Buikstra and Cook, 1980; Mays, S. A., 1997). With so much work done to highlight the necessity for improving standards it is disheartening to observe that many of these issues have apparently been either ignored or only partially acknowledged in the skeletal reports. Of course, it is probable that many of these reports were actually written a long time before they were finally published, so may not reflect current working practices and attitudes. If this is the case then this illustrates the length of time it takes for recommendations and changes in practice to filter through to the level of published skeletal reports. A factor contributing to this slow change could be the level of inertia created by people already established in the field who may be reluctant to change from the familiar way they have always done things to a strange and new procedure. Undoubtedly there are many more reports written a decade or more ago awaiting publication, which will, when published, provide a misleading impression of the working practices of current osteologists. Not all reports providing inadequate data have been written decades ago, however, and there is a real need to ensure that the standards recommended by BABAO (Brickley and McKinley, 2004) become incorporated into the work practiced by osteologists in Britain.

The implications of poor quality skeletal reports are far-reaching. The numbers presented work their way into the literature, and if the data are inaccurate then this provides a misleading impression of the true situation. Future studies may have to rely on skeletal reports to an increased degree, especially if reburial becomes more common. Attempts to study trends in palaeopathology in conjunction with other archaeological evidence over wide geographical areas are crucial in order to enhance understanding of both the disease in question and the interaction between humans and their environment (Mays, S. A., 1997). However, the larger the area and the greater the time period the more impractical it becomes in terms of time and cost for each researcher to record afresh the data from the skeletal collections themselves, and so it becomes necessary to rely on data produced by others. Ortner (1991: p10) has observed that "it is now very difficult for one person to collect all the data needed for a regional study of paleopathology" for reasons of travel, finance, availability of collections and quantity of material available for study. Large scale studies such as this one, or that currently underway to investigate health in Europe, or those conducted by Roberts and Cox (2003), Steckel and Rose (2002a), and Rose *et al.* (1991) would not be possible without the data already collected by others. It is essential that skeletal reports do contribute valuable data to future studies in palaeopathology.

8.4 Recommendations for Future Work

Many limitations have been imposed by the quality of the data used for this research, and consequently most of the apparent trends can only be tentatively identified. Better data need to be collected from skeletal remains in order that age-at-death can be linked directly with data on caries prevalence, and so that changes in the pattern of carious lesions according to tooth type and location can be assessed. Studying a combination of pathological conditions, both dental and skeletal, will help elucidate changes in caries prevalence in relation to diet, as will incorporating environmental and cultural data to a greater degree than was achieved here. More stable isotope studies are required to answer questions concerning diet, for example the amount of seafood consumed by different status groups, and by coastal and inland populations in different periods.

Hopefully this study has highlighted trends that future work can test with better data. Fluctuations in caries prevalence in the Early Medieval period could be investigated in relation to detailed data on changes in diet. For the Late Medieval period, investigation of monastic cemeteries with a view to differentiating between the religious and lay burials could be informative. An examination of sex-differences in caries prevalence in skeletal remains from church contexts would be useful both to compare with the monastic cemeteries and with the trends observed in the preceding periods. The apparent differences between coastal and inland sites in all periods need to be explored, in combination with stable isotope and other environmental and cultural data, to discover whether these trends are real, and if so what might be causing them. Detailed regional studies incorporating environmental data would shed light on patterns of caries prevalence in particular areas. Finally, the chronological period could be expanded to include earlier and later populations.

BIBLIOGRAPHY

Abramson, P. (1987) "The Yorkshire Archaeological Register: 1986" *The Yorkshire Archaeological Journal* **59**, pp 193-201.

Adams, M. (1996) "Excavation of a Pre-Conquest Cemetery at Addingham, West Yorkshire" *Medieval Archaeology* **40**, pp 151-191.

Al-Shammery, A. R. (1999) "Caries Experience of Urban and Rural Children in Saudi Arabia" *Journal of Public Health Dentistry* **59**, pp 60-64.

Ambrose, S. H., Butler, B. M., Hanson, D. B., Hunter-Anderson, R. L. and Krueger, H. W. (1997) "Stable Isotopic Analysis of Human Diet in the Marianas Archipelago, Western Pacific" *American Journal of Physical Anthropology* **104**, pp 343-361.

Anderson, R. J. (1969) "The Relationship Between Dental Condition and the Trace Element Molybdenum" *Caries Research* **3**, pp 75-87.

Anderson, S. (1990) *The Human Skeletal Remains from Staunch Meadow, Brandon, Suffolk.* English Heritage: Ancient Monuments Laboratory Report 99/90: Unpublished.

Anderson, S. (1992) *The Human Skeletal Remains from Monkwearmouth and Jarrow.*

Anderson, S. (1993) "The Human Skeletal Remains from Caister-on-Sea" in Darling, M. J. and Gurney, D. (eds) *Caister-on-Sea. Excavations by Charles Green, 1951-55. East Anglian Archaeology* **60**. Dereham: Field Archaeology Division, Norfolk Museums Service, pp 261-268.

Anderson, S. and Birkett, D. (1991) *The Human Skeletal Remains from Burgh Castle, Norfolk, 1960: Additional Data.* English Heritage: Ancient Monuments Laboratory Report 6/91: Unpublished.

Anderson, S. and Birkett, D. (1993) "The Human Skeletal Remains from Burgh Castle" in Darling, M. J. and Gurney, D. (eds) *Caister-on-Sea. Excavavions by Charles Green, 1951-55. East Anglian Archaeology* **60**. Dereham: Field Archaeology Division, Norfolk Museums Service, pp 256-260.

Anderson, T. and Andrews, J. (1997) "The Human Skeletons" in Parfitt, K. and Brugmann, B. (eds) *The Anglo-Saxon Cemetery on Mill Hill, Deal, Kent. The Society for Medieval Archaeology Monograph Series* **14**. London: The Society for Medieval Archaeology, pp 214-239.

Angel, J. L. (1981) "History and Development of Palaeopathology" *American Journal of Physical Anthropology* **56**, pp 509-515.

Antunes, J. L. F., Junqueira, S. R., Frazão, P., Bisipo, C. M., Pegoretti, T. and Narvai, P. C. (2003) "City-Level Gender Differentials in the Prevalence of Dental Caries and Restorative Dental Treatment" *Health and Place* **9**, pp 231-239.

Asthana, S. (1998) "The Relevance of Place in HIV Transmission and Prevention" in Kearns, R. A. and Gesler, W. M. (eds) *Putting Health into Place. Landscape Identity and Well-being*. Syracuse, New York: Syracuse University Press, pp 168-187.

Aston, M. (1988) "Medieval Fish, Fisheries and Fishponds - Forethoughts" in Aston, M. (ed) *Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports, British Series,* **182(i)**. Oxford; BAR, pp 1-6.

Aston, M. (2000) *Monasteries in the Landscape*. Stroud: Tempus.

Åstrøm, B. D. and Haugejorden, O. (2000) "Oral Hygiene and Sugar Consumption Among Urban and Rural Adolescents in Ghana" *Community Dentistry and Oral Epidemiology* **48**, pp 443-450.

Aufderheide, A. C. and Rodríguez-Martín, C. (1998) *The Cambridge Encyclopedia of Human Palaeopathology*. Cambridge: Cambridge University Press.

Austin, D. (1990) "The 'Proper Study' of Medieval Archaeology" in Austin, D. and Alcock, L. (eds) *From the Baltic to the Black Sea: Studies in Medieval Archaeology*. London: Unwin Hyman, pp 10-42.

Ayers, B. (1985) *Excavations within the North-East Bailey of Norwich Castle, 1979. East Anglian Archaeology* **28**. Dereham: Norfolk Archaeological Trust.

Backer Dirks, O. (1974) "The Benefits of Water Fluoridation" *Caries Research, Supplement* **8**, pp 2-15.

Bain, S. (1983) "Health-Care Problems in North-West Sutherland: a Peripheral Region of Scotland" in McGlashan, N. D. and Blunden, J. R. (eds) *Geographical Aspects of Health: Essays in Honour of Andrew Learmonth*. London: Academic Press, pp 223-240.

Barrett, F. A. (1991) "'Scurvy' Lind's Medical Geography" *Social Science and Medicine* **33**, pp 347-353.

Barrett, F. A. (1993) "A Medical Geography Anniversary" *Social Science and Medicine* **37**, pp 701-710.

Barrett, F. A. (2000) "Finke's 1792 Map of Human Diseases: the First World Disease Map?" *Social Science and Medicine* **50**, pp 915-921.

Barrett, J. (2002) *The Fish Bone from Excavations at Saxon Flixborough, Lincolnshire*. York: University of York: Unpublished.

Bayley, J. (1975) *Chelmsford Dominican Priory. Human Bone Report. Ancient Monuments Laboratory Report* **1890**. English Heritage: Unpublished.

Beckett, S. and Lovell, N. C. (1994) "Dental Disease Evidence for Agricultural Intensification in The Nubian C-Group" *International Journal of Osteoarchaeology* **4**, pp 223-240.

Bell, M. and Walker, M. J. C. (1992) *Late Quaternary Environmental Change: Physical and Human Perspectives*. Harlow: Longman Group UK Ltd.

Berti, P. R. and Leonard, W. R. (1998) "Demographic and Socioeconomic Determinants of Variation in Food and Nutrient Intake in an Andean Community" *American Journal of Physical Anthropology* **105**, pp 407-417.

Birkett, D. A. (1986) "The Human Burials" (pp 291-298) in Daniels, R. (ed) The Excavation of the Church of the Franciscans, Hartlepool, Cleveland. *Archaeological Journal* **143**, pp 260-304.

Bishop, M. W. (1983) "Burials from the Cemetery of the Hospital of St. Leonard, Newark, Nottinghamshire" *Transactions of the Thoroton Society of Nottinghamshire* **87**, pp 23-35.

Black, M. (1992) *The Medieval Cookbook.* London: British Museum Press.

Blair, J. (1988) "Minster Churches in the Landscape" in Hooke, D. (ed) *Anglo-Saxon Settlements*. Oxford: Basil Blackwell, pp 35-58.

Blau, S., Kennedy, B. J. and Kim, J. Y. (2002) "An Investigation of Possible Fluorosis in Human Dentition Using Synchrotron Radiation" *Journal of Archaeological Science* **29**, pp 811-817.

Boddington, A. (1996) *Raunds Furnells: The Anglo-Saxon Church and Churchyard.* London: English Heritage.

Boghi, F. and Boylston, A. (1997) *The Medieval Cemetery of Pennell Street, Lincoln, Lincolnshire. Report on the Human Skeletal Remains.* Calvin Wells Laboratory, University of Bradford: Unpublished.

Bond, C. J. (1988) "Monastic Fisheries" in Aston, M. (ed) *Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports, British Series,* **182(i)**. Oxford; BAR, pp 69-112.

Bond, C. J. (2004) *Monastic Landscapes.* Stroud: Tempus.

Boocock, P. A., Manchester, K. and Roberts, C. A. (1995) *The Human Remains from Eccles, Kent.* Calvin Wells Laboratory, University of Bradford: Unpublished.

Boocock, P. A. and Roberts, C. A. (1994) *Ysgol Twm O'r Nant, Denbigh, Clwyd, Human Bone Report.* Calvin Wells Laboratory, University of Bradford: Unpublished.

Boulter, S. and Rega, E. (1993) *Report of Human Remains from Blackgate, Newcastle-upon-Tyne.* University of Sheffield: Unpublished.

Boyle, A., Dodd, A., Miles, D. and Mudd, A. (1995) *Two Oxfordshire Anglo-Saxon Cemeteries: Berinsfield and Didcot. Thames Valley Landscapes Monograph* **8**. Oxford: Oxford Archaeological Unit.

Boyle, A., Jennings, D., Miles, D. and Palmer, S. (1998) *The Anglo-Saxon Cemetery at Butler's Field, Lechlade, Gloucestershire. Volume 1: Prehistoric and Roman Activity and Anglo-Saxon Grave Catalogue. Thames Valley Landscapes Monograph* **10**. Oxford: Oxford Archaeological Unit.

Boylston, A., Coughlan, J. and Roberts, C. A. (1998a) *Report on the Analysis of the Human Skeletal Remains from Chevington Chapel, Northumberland.* Calvin Wells Laboratory, University of Bradford: Unpublished.

Boylston, A. and Roberts, C. A. (1996) "The Human Bone" (pp 173-180) in Adams, M. (ed) Excavation of a Pre-Conquest Cemetery at Addingham, West Yorkshire. *Medieval Archaeology* **40**, pp 151-191.

Boylston, A., Wiggins, R. and Roberts, C. A. (1998b) "Human Skeletal Remains" in Drinkall, G. and Foreman, M. (eds) *The Anglo-Saxon Cemetery at Castledyke South, Barton-on-Humber. Sheffield Excavation Reports* **6**. Sheffield: Sheffield Academic Press Ltd, pp 221-236.

Brash, J. C. (1922-23) "Notes on the Cranial and Other Skeletal Characteristics" (pp 106-110) in Humphreys, J., Ryland, J. W., Barnard, E. A. B., Wellstood, F. C. and Barnett, T. G. (eds) An Anglo-Saxon Cemetery at Bidford-on-Avon, Warwickshire. *Archaeologia* **73**, pp 89-116.

Brash, J. C. (1923-24) "Notes on the Bones Recovered During the 1923 Excavations" (pp 281-282) in Humphreys, J., Ryland, J. W., Wellstood, F. C., Barnard, E. A. B. and Barnett, T. G. (eds) An Anglo-Saxon Cemetery at Bidford-on-Avon, Warwickshire: Second Report on the Excavations. *Archaeologia* **74**, pp 271-288.

Brickley, M. and McKinley, J. I. (eds) (2004) *Guidelines to the Standards for Recording Human Remains. Institute of Field Archaeologists Paper No.* **7**. Southampton and Reading: British Association of Biological Anthropology and Osteoarchaeology and the Institute of Field Archaeologists.

Brieger, G. (1993) "The Historiography of Medicine" in Bynum, W. F. and Porter, R. (eds) *Companion Encyclopedia of the History of Medicine.* **1**. London and New York: Routledge, pp 24-44.

Brooke, C. (2003) *The Age of the Cloister: The Story of Monastic Life in the Middle Ages*. Stroud: Sutton Publishing Ltd.

Brothwell, D. and Sandison, A. T. (eds) (1967) *Diseases in Antiquity. A Survey of the Diseases, Injuries and Surgery of Early Populations*. Springfield, Illinois: Charles C Thomas.

Brothwell, D. R. (1959) "Teeth in Earlier Human Populations" *Proceedings of the Nutritional Society* **18**, pp 59-65.

Brothwell, D. R. (1963) "The Macroscopic Dental Pathology of some Earlier Human Populations" in Brothwell, D. R. (ed) *Dental Anthropology*. Oxford: Pergamon Press, pp 271-288.

Brothwell, D. R. and Brothwell, P. (1998) *Food in Antiquity*. Baltimore & London: The John Hopkins University Press.

Broukal, Z. and Zajícek, O. (1974) "Amount and Distribution of Extracellular Polysaccharides in Dental Microbial Plaque" *Caries Research* **8**, pp 97-104.

Buckberry, J. L. and Chamberlain, A. T. (2002) "Age Estimation From the Auricular Surface of the Ilium: A Revised Method" *American Journal of Physical Anthropology* **119**, pp 231-239.

Budd, P., Millard, A., Chenery, C., Lucy, S. and Roberts, C. (2004) "Investigating Population Movement by Stable Isotope Analysis: A Report from Britain" *Antiquity* **78**, pp 127-141.

Buikstra, J. E. and Cook, D. C. (1980) "Palaeopathology: An American Account" *Annual Review of Anthropology* **9**, pp 433-470.

Buikstra, J. E. and Ubelaker, D. H. (eds) (1994) *Standards for Data Collection from Human Skeletal Remains.* Arkansas: Arkansas Archeological Survey Research Series No. 44.

Burton, J. (1994) *Monastic and Religious Orders in Britain 1000-1300.* Cambridge: Cambridge University Press.

Caffell, A. C., Roberts, C. A., Janaway, R. C. and Wilson, A. S. (2001) "Pressures on Osteological Collections - the Importance of Damage Limitation" in Williams, E. (ed) *Human Remains: Conservation, Retrieval and Analysis. British Archaeological Reports, International Series,* **934**. Proceedings of a conference held in Williamsburg, VA, Nov 7-11th 1999: Oxford; Archaeopress, pp 187-197.

Camargo, J. A. (2003) "Fluoride Toxicity to Aquatic Organisms: A Review" *Chemosphere* **50**, pp 251-264.

Camerini, J. R. (2000) "Heinrich Berghaus's Map of Human Diseases" in Rupke, N. A. (ed) *Medical Geography in Historical Perspective (Medical History Supplement No. 20).* London: The Wellcome Trust Centre for the History of Medicine at UCL, pp 186-208.

Cameron, M. L. (1993) *Anglo-Saxon Medicine.* Cambridge: Cambridge University Press.

Campain, A. C., Morgan, M. V., Evans, R. W., Ugoni, A., Adams, G. G., Conn, J. A. and Watson, M. J. (2003) "Sugar-Starch Combinations in Food and the Relationship to Dental Caries in Low-Risk Adolescents" *European Journal of Oral Sciences* **111**, pp 316-325.

Cardwell, P. (1995) "Excavation of the Hospital of St. Giles by Brompton Bridge, North Yorkshire" *The Archaeological Journal* **152**, pp 109-245.

Cardy, A. (1997) "The Human Bones" in Hill, P. (ed) *Whithorn and St Ninian. The Excavation of a Monastic Town, 1984-91.* Stroud: Sutton Publishing, pp 519-562.

Carlin, M. (1998) "Fast Food and Urban Living Standards in Medieval England" in Carlin, M. and Rosenthal, J. T. (eds) *Food and Eating in Medieval Europe.* London: The Hambledon Press, pp 27-51.

Chisholm, B. S., Nelson, D. E. and Schwarcz, H. P. (1983) "Marine and Terrestrial Protein in Prehistoric Diets on the British Columbia Coast" *Current Anthropology* **24**, pp 396-398.

Chundun, Z. and Roberts, C. A. (1995) "Human Skeletal Remains" (pp 214-218) in Cardwell, P. (ed) Excavation of the Hospital of St. Giles by Brompton Bridge, North Yorkshire. *The Archaeological Journal* **152**, pp 109-245.

Cipolla, C. M. (1992) *Miasmas and Disease. Public Health and the Environment in the Pre-Industrial Age.* New Haven and London: Yale University Press.

Clark, J. (1841) *The Sanative Influence of Climate: with an Account of the Best Places of Resort for Invalids in England, the South of Europe, &c.* London: John Murray.

Clarkson, B. H. (1999) "Introduction to Cariology" *Dental Clinics of North America* **43**, pp 569-578.

Cliff, A. D. and Haggett, P. (1988) *Atlas of Disease Distributions: Analytic Approaches to Epidemiological Data.* Oxford: Blackwell.

Coley, N. G. (1979) ""Cures Without Care" "Chymical Physicians" and Mineral Waters in Seventeenth-Century English Medicine" *Medical History* **23**, pp 191-214.

Committee on Diet and Health, Food and Nutrition Board, Commission on Life Sciences and National Research Council (1989) *Diet and Health. Implications for Reducing Chronic Disease Risk.* Washington DC: National Academy Press.

Conheeney, J. (1992) *First Draft of Human Bone Report for St. Mary Spital. St. Mary Spital Research Archive (Enviro) Specialist Reports 3* MoLSS, London: Unpublished.

Conheeney, J. (1993) *Rewrite of Two Holy Trinity Reports into One Publication Report.* MoLAS, London: Unpublished Report HUM/REP/02/93.

Conheeney, J. (1997) "The Human Bone" in Thomas, C., Sloane, B. and Phillpotts, C. (eds) *Excavations at the Priory and Hospital of St. Mary Spital, London. MoLAS Monograph* **1**. London: MoLAS, pp 218-231.

Conheeney, J. (?date) *Human Skeletal Remains.* MoLSS, London: Unpublished.

Connell, B. (2002) *The Cemetery Population from Spitalfields Market, London: An Osteological Pilot Study and Post-excavation Assessment.* MoLSS, London: Unpublished.

Cook, D. C. and Hunt, K. D. (1998) "Sex Differences in Trace Elements: Status or Self-Selection?" in Grauer, A. L. and Stuart-Macadam, P. (eds) *Sex and Gender in Paleopathological Perspective.* Cambridge: Cambridge University Press, pp 64-78.

Corbett, M. E. and Moore, W. J. (1976) "Distribution of Caries in Ancient British Populations IV. The 19th Century" *Caries Research* **10**, pp 401-414.

Cosman, M. P. (1976) *Fabulous Feasts: Medieval Cookery and Ceremony.* New York: George Braziller.

Cox, M. (1995) "A Dangerous Assumption: Anyone can be a Historian! The Lessons from Christ Church, Spitalfields" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies.* Toronto: Canadian Scholars' Press Inc., pp 19-29.

Cox, M. (1999) "The Human Bones: Analysis and Interpretation of the Skeletal Material" in Haughton, C. and Powlesland, D. (eds) *West Heslerton. The Anglian Cemetery. Volume 1: The Excavation and Discussion of the Evidence.* Yedingham: The Landscape Research Centre, pp 172-188.

Coy, J. (1996) "Medieval Records Versus Excavation Results - Examples from Southern England" *Archaeofauna* **5**, pp 55-63.

Cramp, R. (1969) "Excavation at the Saxon Monastic Sites of Wearmouth and Jarrow, Co. Durham: An Interim Report" *Medieval Archaeology: Journal of the Society for Medieval Archaeology* **13**, pp 21-66.

Cramp, R. (1976) "Monastic Sites" in Wilson, D. M. (ed) *The Archaeology of Anglo-Saxon England.* Cambridge: Cambridge University Press, pp 201-252.

Cramp, R. (1999) "Monkwearmouth and Jarrow in their Continental Context" in Karkov, C. E. (ed) *The Archaeology of Anglo-Saxon England: Basic Readings.* New York and London: Garland Publishing Inc, pp 137-153.

Crawford, A. (ed) (1992) *The Household Books of John Howard, Duke of Norfolk. 1462-1471, 1481-1483.* Stroud: Alan Sutton for Richard III & Yorkist History Trust.

Cronyn, J. (1990) *The Elements of Archaeological Conservation.* London: Routledge.

Cross, J. F. and Bruce, M. F. (1989) "The Skeletal Remains" in Stones, J. A. (ed) *Three Scottish Carmelite Friaries: Excavations at Aberdeen, Linlithgow and Perth 1980-1986. Monograph Series* **6**. Edinburgh: Society of Antiquaries of Scotland, pp 119-141.

Cucina, A. and Tiesler, V. (2003) "Dental Caries and Antemortem Tooth Loss in the Northern Peten Area, Mexico: A Biocultural Perspective on Social Status Differences Among the Classic Maya" *American Journal of Physical Anthropology* **122**, pp 1-10.

Dalland, M. (1992) "Long Cist Burials at Four Winds, Longniddry, East Lothian" *Proceedings of the Society of Antiquaries of Scotland* **122**, pp 197-206.

Dallas, C. (1993) *Excavations in Thetford by B. K. Davison between 1964 and 1970. East Anglian Archaeology* **62**. Dereham: Field Archaeology Division, Norfolk Museums Service.

Daniell, C. (1997) *Death and Burial in Medieval England, 1066-1550.* London & New York: Routledge.

Daniell, C. and Thompson, V. (1999) "Pagans and Christians: 400-1150" in Jupp, P. C. and Gittings, C. (eds) *Death in England: An Illustrated History.* Manchester: Manchester University Press, pp 65-89.

Daniels, R. (1986) "The Excavation of the Church of the Franciscans, Hartlepool, Cleveland" *The Archaeological Journal* **143**, pp 260-304.

Dark, P. (2000) *The Environment of Britain in the First Millennium AD.* London: Duckworth.

Darling, M. J. and Gurney, D. (1993) *Caister-on-Sea. Excavations by Charles Green, 1951-55. East Anglian Archaeology* **60**. Dereham: Field Archaeology Division, Norfolk Museums Service.

Davies, R. P. O., Tocque, K., Bellis, M. A., Rimmington, T. and Davies, P. D. O. (1999) "Historical Decline in Tuberculosis: Improving Social Conditions or Natural Selection?" in Pálfi, G., Dutour, O., Deák, J. and Hutás, I. (eds) *Tuberculosis: Past and Present.* Szeged, Hungary: Golden Book Publisher Ltd., Tuberculosis Foundation, pp 87-92.

Davies, S. M. (1985) "The Excavation of an Anglo-Saxon Cemetery (and Some Prehistoric Pits) at Charlton Plantation, near Downton" *The Wiltshire Archaeological and Natural History Magazine* **79**, pp 109-154.

Dawes, J. D. and Magilton, J. R. (1980) *The Cemetery of St Helen-on-the-Walls, Aldwark. The Archaeology of York: The Medieval Cemeteries* **12/1**. York: Council for British Archaeology for York Archaeological Trust.

Denston, R. B. and Noble, H. W. (1956) "The Human Remains and Dental Report" (pp 112-117) in Evison, V. I. (ed) An Anglo-Saxon Cemetery at Holborough, Kent. *Archaeologia Cantiana* **70**, pp 84-141.

Department of Health (1989) *Dietary Sugars and Human Disease. Report of the Panel on Dietary Sugars. Report on Health and Social Subjects* **37**. London: HMSO.

Department of the Environment (1991) *Digest of Environmental Protection and Water Statistics*. **14**. London: HMSO.

Department of the Environment Transport and the Regions (1998) *Digest of Environmental Statistics. No.* **20**. London: The Stationery Office.

Detsicas, A. P. (1966) "Excavations at Eccles, 1965. Fourth Interim Report" *Archaeologia Cantiana* **81**, pp 44-52.

Detsicas, A. P. (1971) "Excavations at Eccles, 1970. Ninth Interim Report" *Archaeologia Cantiana* **86**, pp 25-34.

Detsicas, A. P. (1972) "Excavations at Eccles, 1971. Tenth Interim Report" *Archaeologia Cantiana* **87**, pp 101-110.

Detsicas, A. P. (1973) "Excavations at Eccles, 1972. Eleventh Interim Report" *Archaeologia Cantiana* **88**, pp 73-80.

Detsicas, A. P. (1974) "Excavations at Eccles, 1973. Twelfth Interim Report" *Archaeologia Cantiana* **89**, pp 119-134.

Detsicas, A. P. (1975) "Excavations at Eccles, 1974. Thirteenth Interim Report" *Archaeologia Cantiana* **90**, pp 41-45.

Detsicas, A. P. (1976) "Excavations at Eccles, 1975. Fourteenth Interim Report" *Archaeologia Cantiana* **91**, pp 157-163.

Detsicas, A. P. (1989) "Excavations at Eccles: A Progress Report" *Archaeologia Cantiana* **107**, pp 83-88.

Dormandy, T. (1999) *The White Death: A History of Tuberculosis*. London and Rio Grande: The Hambledon Press.

dos Santos, M. N., dos Santos, L. M., Francisco, S. B. and Cury, J. A. (2002) "Relationship among Dental Plaque Composition, Daily Sugar Exposure and Caries in the Primary Dentition" *Caries Research* **36**, pp 347-352.

Douven, W. and Scholten, H. J. (1995) "Spatial Analysis in Health Research" in de Lepper, M. J. C., Scholten, H. J. and Stern, R. M. (eds) *The Added Value of Geographical Information Systems in Public and Environmental Health*. Dordrecht: Kluwer Academic Publishers, pp 117-133.

Dowd, F. J. (1999) "Saliva and Dental Caries" *Dental Clinics of North America* **43**, pp 579-597.

Down, A. and Welch, M. (1990) *Chichester Excavations*. **7**. Chichester: Chichester District Council.

Downs, D. L. (1979) *Human Skeletal Remains - Holy Trinity Priory 1979*. MoLAS, London: Unpublished Report HUM/REP/01/79.

Drinkall, G. and Foreman, M. (1998) *The Anglo-Saxon Cemetery at Castledyke South, Barton-on-Humber. Sheffield Excavation Reports* **6**. Sheffield: Sheffield Academic Press Ltd.

Drummond, J. C. and Wilbraham, A. (1957) *The Englishman's Food: A History of Five Centuries of English Diet.* London: Jonathan Cape.

Duhig, C. (1998) "The Human Skeletal Material" in Malim, T. and Hines, J. (eds) *The Anglo-Saxon Cemetery at Edix Hill (Barrington A), Cambridgeshire. CBA Research Report* **112**. York: Council for British Archaeology, pp 154-199.

Dunn, C. E. and Kingham, S. P. (1996a) "Establishing Links Between Air Quality and Health: Searching for the Impossible?" *Social Science and Medicine* **42**, pp 831-841.

Dunn, C. E. and Kingham, S. P. (1996b) "Modelling Air Quality and the Effects on Health in a GIS Framework" in Parker, D. (ed) *Innovations in GIS 3: Selected Papers from the Third National Conference on GIS Research UK (GISRUK).* London: Taylor & Francis Ltd., pp 205-213.

Dunn, C. E., Woodhouse, J., Bhopal, R. S. and Acquilla, S. D. (1995) "Asthma and Factory Emissions in Northern England: Addressing Public Concern by Combining Geographical and Epidemiological Methods" *Journal of Epidemiology and Community Health* **49**, pp 395-400.

Dyer, C. (1988) "The Consumption of Fresh-Water Fish in Medieval England" in Aston, M. (ed) *Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports, British Series,* **182(i)**. Oxford; BAR: pp 27-38.

Dyer, C. (1989) *Standards of Living in the Later Middle Ages: Social Change in England c. 1200-1520.* Cambridge: Cambridge University Press.

Dyer, C. (1998) "Did the Peasants Really Starve in Medieval England?" in Carlin, M. and Rosenthal, J. T. (eds) *Food and Eating in Medieval Europe.* London: The Hambledon Press, pp 53-71.

Dyer, C. (2000) *Everyday Life in Medieval England.* London: Hambledon and London.

Edgar, W. (1990a) "Dental Plaque" in Elderton, R. J. (ed) *Clinical Dentistry in Health and Disease: The Dentition and Dental Care.* Oxford: Heinemann Medical Books, pp 87-108.

Edgar, W. (1990b) "Fluorides" in Elderton, R. J. (ed) *Clinical Dentistry in Health and Disease: The Dentition and Dental Care.* Oxford: Heinemann Medical Books, pp 109-123.

Ekanayake, L. and van der Hoek, W. (2002) "Dental Caries and Developmental Defects of Enamel in Relation to Fluoride Levels in Drinking Water" *Caries Research* **36**, pp 398-404.

Elderton, R. J. (1990) "The Prevention of Caries and Periodontal Diseases" in Elderton, R. J. (ed) *Clinical Dentistry in Health and Disease: The Dentition and Dental Care.* Oxford: Heinemann Medical Books, pp 139-163.

Enghoff, I. B. (2000) "Fishing in the Southern North Sea Region from the 1st to the 16th Century AD: Evidence from Fish Bones" *Archaeofauna* **9**, pp 59-132.

Ensor, S., Boylston, A. and Roberts, C. A. (1993) *Report on Human Skeletal Material from Milton Keynes Village*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Enwonwu, C. O. (1974) "Socio-Economic Factors in Dental Caries Prevalence and Frequency in Nigerians. An Epidemiological Study" *Caries Research* **8**, pp 155-171.

Erdal, Y. S. and Duyar, I. (1999) "Brief Communication: A New Correction Procedure for Calibrating Dental Caries Frequency" *American Journal of Physical Anthropology* **108**, pp 237-240.

Ericsson, Y. (1969) "Fluoride Excretion in Human Saliva and Milk" *Caries Research* **3**, pp 159-166.

Ericsson, Y. (1974) "Report on the Safety of Drinking Water Fluoridation" *Caries Research, Supplement* **8**, pp 16-27.

Esmonde Cleary, S. (1999) "Roman Britain: Civil and Rural Society" in Hunter, J. and Ralston, I. (eds) *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution*. New York: Routledge, pp 157-175.

Ettinger, R. L. (1999) "Epidemiology of Dental Caries: A Broad Review" *Dental Clinics of North America* **43**, pp 679-694.

Evison, V. I. (1956) "An Anglo-Saxon Cemetery at Holborough, Kent" *Archaeologia Cantiana* **70**, pp 84-141.

Evison, V. I. (1987) *Dover: The Buckland Anglo-Saxon Cemetery*. London: Historic Buildings and Monuments Commission for England.

Evison, V. I. (1994) *An Anglo-Saxon Cemetery at Great Chesterford, Essex. CBA Research Report* **91**. York: Council for British Archaeology.

Evison, V. I. and Hill, P. (1996) *Two Anglo-Saxon Cemeteries at Beckford, Hereford and Worcester. CBA Research Report* **103**. York: Council for British Archaeology.

Eyles, J. and Woods, K. J. (1983) *The Social Geography of Medicine and Health*. London & Canberra: Croom Helm.

Fabian Society (1975) *Improving the Dental Health Service. Young Fabian Pamphlet* **41**. London: Fabian Society.

Fagan, B. (2000) *The Little Ice Age: How Climate Made History, 1300-1850*. New York: Basic Books.

Fielden, K. J. (1978) "The Skeletal Material" (pp 62-65) in Gingell, C. J. (ed) The Excavation of an Early Anglo-Saxon Cemetery at Collingbourne Ducis. *The Wiltshire Archaeological Magazine* **70/71**, pp 61-98.

Firth, J. (1974) *Reminisces of an Orkney Parish*. Stromness: Orkney Natural History Society.

Fisher, C. T. (1997) "Past Human Exploitation of Birds on the Isle of Man" *International Journal of Osteoarchaeology* **7**, pp 292-297.

Fletcher, M. and Lock, G. R. (1991) *Digging Numbers: Elementary Statistics for Archaeologists*. Oxford: Oxford University Committee for Archaeology.

Fooce, C. D. and Sciulli, P. W. (2003) *Dental Health in North America. In Poster Presented at the American Association of Physical Anthropology Meeting, Tempe, Arizona: 21st -26th April 2003*

Fowler, P. (2002) *Farming in the First Millennium AD.* Cambridge: Cambridge University Press.

Freeth, C. M. (1999) *Dental Health in Biocultural Perspective: The Prevalence, Pattern and Distribution of the Dental Diseases in British Archaeological Populations from a Geographic, Demographic and Temporal Viewpoint. Department of Archaeological Sciences* Bradford: University of Bradford.

Frost, W. H. (1965) *Snow on Cholera: being a reprint of two papers by John Snow M.D. together with a biographical memoir by B.W. Richardson and an introduction by Wade Hampton Frost, M.D.* London: Hafner Publishing Company.

Fry, T. (1981) *The Rule of St. Benedict in Latin and English with Notes.* Collegeville, Minnesota: The Liturgical Press.

Galloway, J. A. (1998) "Driven by Drink? Ale Consumption and the Agrarian Economy of the London Region, c. 1300-1400" in Carlin, M. and Rosenthal, J. T. (eds) *Food and Eating in Medieval Europe.* London: The Hambledon Press, pp 87-100.

Galloway, J. H. (2000) "Sugar" in Kiple, K. F. and Ornelas, K. C. (eds) *The Cambridge World History of Food.* **1**. Cambridge: Cambridge University Press, pp 437-449.

García-Closas, R., García-Closas, M. and Serra-Majem, L. (1997) "A Cross-Sectional Study of Dental Caries, Intake of Confectionary and Foods Rich in Starch and Sugars, and Salivary Counts of *Streptococcus mutans* in Children in Spain" *American Journal of Clinical Nutrition* **66**, pp 1257-1263.

Garland, A. N. (1987) "A Histological Study of Archaeological Bone Decomposition" in Boddington, A., Garland, A. N. and Janaway, R. C. (eds) *Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science.* Manchester: Manchester University Press, pp 109-126.

Garland, A. N. and Janaway, R. C. (1989) "The Taphonomy of Inhumation Burials" in Roberts, C. A., Lee, F. and Bintliff, J. (eds) *Burial Archaeology: Current Research, Methods and Developments. British Archaeological Reports, British Series,* **211**. Oxford; BAR, pp 15-37.

Gesler, W. M. (1998) "Bath's Reputation as a Healing Place" in Kearns, R. A. and Gesler, W. M. (eds) *Putting Health into Place. Landscape Identiry and Well-being.* Syracuse, New York: Syracuse University Press, pp 17-35.

Gilbert, E. W. (1958) "Pioneer Maps of Health and Disease in England" *The Geographical Journal* **124**, pp 172-183.

Gilchrist, R. (1995) *Contemplation and Action: The Other Monasticism.* London and New York: Leicester University Press.

Giles, G. G. (1983) "The Utility of the Relative Risk Ratio in Geographical Epidemiology: Hodgkin's Disease in Tasmania 1972-1980, a Case Control Study" in McGlashan, N. D. and Blunden, J. R. (eds) *Geographical Aspects of Health: Essays in Honour of Andrew Learmonth.* London: Academic Press, pp 361-374.

Gingell, C. J. (1978) "The Excavation of an Early Anglo-Saxon Cemetery at Collingbourne Ducis" *The Wiltshire Archaeological Magazine* **70/71**, pp 61-98.

Global History of Health Project (2002) "European Module" *http://global.sbs.ohio-state.edu/european_module.htm* Accessed 26th September 2004

Golding, B. (1995) *Gilbert of Sempringham and the Gilbertine Order c. 1130 - c. 1300.* Oxford: Clarendon Press.

Gottfried, R. S. (1978) *Epidemic Disease in Fifteenth Century England: The Medical Response and the Demographic Consequences.* Leicester: Leicester University Press.

Graham, A. H. and Davies, S. M. (1993) *Excavations in the Town Centre of Trowbridge, Wiltshire 1977 and 1986-88. Wessex Archaeology Report* **2**. Salisbury: Trust for Wessex Archaeology Ltd.

Grainger, I., Hawkins, D., Falcini, P. and Mills, P. (1988) "Excavations at the Royal Mint Site 1986-1988" *The London Archaeologist* **5**, pp 429-436.

Grant, E. (1988) "Marine and River Fishing in Medieval Somerset: Fishbone Evidence from Langport" in Aston, M. (ed) *Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports, British Series,* **182(i)**. Oxford; BAR, pp 409-416.

Gray, M. M. and Davies-Slowik, J. (2001) "Changes in the Prevalence of 5-Year-Old Children with No Experience of Decay in Dudley Towns Since the Implementation of Fluoridation Schemes in 1987" *British Dental Journal* **190**, pp 30-32.

Gray, P. G., Todd, J. E., Slack, G. L. and Bulman, J. S. (1970) *Adult Dental Health in England and Wales in 1968.* London: Her Majesty's Stationery Office.

Grenby, T. H., Andrews, A. T., Mistry, M. and Williams, R. J. H. (2001) "Dental Caries-Protective Agents in Milk and Milk Products: Investigations in Vitro" *Journal of Dentistry* **29**, pp 83-92.

Gripp, V. C. and Schlagenhauf, U. (2002) "Prevention of Early Mutans Streptococci Transmission in Infants by Professional Tooth Cleaning and Chlorhexidine Varnish Treatment of the Mother" *Caries Research* **36**, pp 366-372.

Hackett, C. J. (1967) "The Human Treponematoses" in Brothwell, D. and Sandison, A. T. (eds) *Diseases in Antiquity. A Survey of the Diseases, Injuries and Surgery of Early Populations.* Springfield, Illinois: Charles C Thomas, pp 152-169.

Hadjimarkos, D. M. (1969) "Selenium: A Caries-Enhancing Trace Element" *Caries Research* **3**, pp 14-22.

Hadley, D. M. (2000) *The Northern Danelaw: Its Social Structure, c. 800-1100.* London & New York: Leicester University Press.

Hagen, A. (1992) *A Handbook of Anglo-Saxon Food: Processing and Consumption.* Pinner: Anglo-Saxon Books.

Hagen, A. (1995) *A Second Handbook of Anglo-Saxon Food and Drink: Production and Distribution*. Hockwold cum Wilton: Anglo-Saxon Books.

Hall, D. (1988) "The Late Saxon Countryside: Villages and their Fields" in Hooke, D. (ed) *Anglo-Saxon Settlements*. Oxford: Basil Blackwell, pp 99-122.

Hall, R. A. and Whyman, M. (1996) "Settlement and Monasticism at Ripon, North Yorkshire, from the 7th to 11th Centuries AD" *Medieval Archaeology* **40**, pp 62-150.

Hammond, P. W. (1993) *Food and Feast in Medieval England*. Stroud: Sutton Publishing.

Hannaway, C. (1993) "Environment and Miasmata" in Bynum, W. F. and Porter, R. (eds) *Companion Encyclopedia of the History of Medicine*. **1**. London and New York: Routledge, pp 292-308.

Hardwick, J. L. (1960) "The Incidence and Distribution of Caries Throughout the Ages in Relation to the Englishman's Diet" *British Dental Journal* **108**, pp 9-17.

Harman, M. (1981) "Human Remains from Machrins, Colonsay" (pp 276) in Ritchie, J. N. G. (ed) Excavations at Machrins, Colonsay. *Proceedings of the Society of Antiquaries of Scotland* **111**, pp 263-281.

Harman, M. (1987) "The Human Skeleton" (pp 153) in Welander, R. D. E., Batey, C. and Cowie, T. G. (eds) A Viking Burial from Kneep, Uig, Isle of Lewis. *Proceedings of the Society of Antiquaries of Scotland* **117**, pp 149-174.

Harman, M. (1990) "The Human Remains" in Down, A. and Welch, M. G. (eds) *Chichester Excavations*. **7**. Chichester: Chichester District Council, pp 183-194.

Harman, M. (1992) "Human Bone from 1983" (pp 214-215) in Scull, C. (ed) Excavation and Survey at Watchfield, Oxfordshire, 1983-92. *The Archaeological Journal* **149**, pp 124-281.

Harman, M. (1993) "General Description of the Skeletons; Explanation of the Catalogue Entries; The Human Burials: Discussion" in Kinsley, A. G. (ed) *Broughton Lodge. Excavations on the Romano-British Settlement and Anglo-Saxon Cemetery at Broughton Lodge, Willoughby-on-the-Wolds, Nottinghamshire, 1964-8. Nottingham Archaeological Monographs* **4**. Nottingham: Department of Classical and Archaeological Studies (Archaeology Section), University of Nottingham, pp 56-58.

Harman, M. (1995) "The Human Bones" in Boyle, A., Dodd, A., Miles, D. and Mudd, A. (eds) *Two Oxfordshire Anglo-Saxon Cemeteries: Berinsfield and Didcot. Thames Valley Landscapes Monograph* **8**. Oxford: Oxford Archaeological Unit, pp 106-108.

Harman, M. (1998) "The Human Remains" in Boyle, A., Jennings, D., Miles, D. and Palmer, S. (eds) *The Anglo-Saxon Cemetery at Butler's Field, Lechlade, Gloucestershire. Volume 1: Prehistoric and Roman Activity and Anglo-Saxon Grave Catalogue. Thames Valley Landscapes Monograph* **10**. Oxford: Oxford Archaeological Unit, pp 43-52.

Harrison, M. (2000) "Differences in Degree: Representations of India in British Medical Topography, 1820-c.1870" in Rupke, N. A. (ed) *Medical Geography in Historical Perspective (Medical History Supplement No. 20).* London: The Wellcome Trust Centre for the History of Medicine at UCL, pp 51-69.

Harvey, B. (1993) *Living and Dying in England, 1100-1540. The Monastic Experience.* Oxford: Clarendon Press.

Harvey, P. D. A. (1987) "Local and Regional Cartography in Medieval Europe" in Harley, J. B. and Woodward, D. (eds) *The History of Cartography: Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean.* **1**. Chicago & London: Chicago University Press, pp 464-501.

Harvey, P. D. A. (1993) *Maps in Tudor England.* London: British Library & Public Records Office.

Haughton, C. and Powlesland, D. (1999a) *West Heslerton. The Anglian Cemetery. Volume 1: The Excavation and Discussion of the Evidence.* Yedingham: The Landscape Research Centre.

Haughton, C. and Powlesland, D. (1999b) *West Heslerton. The Anglian Cemetery. Volume 2: Catalogue of the Anglian Graves and Associated Assemblages.* Yedingham: The Landscape Research Centre.

Hawkes, S. C. and Grainger, G. (2003) *The Anglo-Saxon Cemetery at Worthy Park, Kingsworthy, near Winchester, Hampshire. Oxford School of Archaeology Monograph* **59**. Oxford: Oxford School of Archaeology.

Hawkes, S. C. and Wells, C. (1983) "The Inhumed Skeletal Material from an Early Anglo-Saxon Cemetery in Worthy Park, Kingsworthy, Hampshire, South England" *Paleobios* **1**, pp 3-36.

Hawkins, D. (1990) "The Black Death and the New London Cemeteries of 1348" *Antiquity* **64**, pp 637-642.

Heighway, C. and Bryant, R. (1999) *The Golden Minster. The Anglo-Saxon Minster and Later Medieval Priory of St Oswald at Gloucester. CBA Research Report* **117**. York: Council for British Archaeology.

Henderson, J. (1985) "The Human Skeletal Material" (pp 143-145) in Davies, S. M. (ed) The Excavation of an Anglo-Saxon Cemetery (and Some Prehistoric Pits) at Charlton Plantation, near Downton. *The Wiltshire Archaeological and Natural History Magazine* **79**, pp 109-154.

Henderson, J. (1987) "Factors Determining the State of Preservation of Human Remains" in Boddington, A., Garland, A. N. and Janaway, R. C. (eds) *Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science.* Manchester: Manchester University Press, pp 43-54.

Henderson, J. D. (1990) "The Human Skeletal Remains" in McCarthy, M. R. (ed) *A Roman, Anglian and Medieval Site at Blackfriars Street, Carlisle: Excavations 1977-9. Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **4**. Kendal: Cumberland and Westmorland Antiquarian and Archaeological Society, pp 330-355.

Herod, E. L. (1991) "The Effect of Cheese on Dental Caries: A Review of the Literature" *Australian Dental Journal* **36**, pp 120-125.

Hill, P. (ed) (1997) *Whithorn and St Ninian. The Excavation of a Monastic Town, 1984-91*. Stroud: Sutton Publishing.

Hills, C. (1999) "Early Historic Britain" in Hunter, J. and Ralston, I. (eds) *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution*. New York: Routledge, pp 176-193.

Hillson, S. W. (1979) "Diet and Dental Disease" *World Archaeology* **11**, pp 147-162.

Hillson, S. W. (1996) *Dental Anthropology*. Cambridge: Cambridge University Press.

Hillson, S. W. (2001) "Recording Dental Caries in Archaeological Human Remains" *International Journal of Osteoarchaeology* **11**, pp 249-289.

Hinchliffe, J. (1984) "Excavations at Canon Street 1977" in Leach, P. (ed) *The Archaeology of Taunton: Excavations and Fieldwork to 1980. Western Archaeological Trust Excavation Monograph* **8**. Gloucester: Alan Sutton Publishing, pp 106-111.

Hinton, D. A. (1990) *Archaeology, Economy and Society: England from the Fifth to the Fifteenth Century*. London: Seaby.

Hobhouse, H. (1999) *Seeds of Change: Six Plants That Transformed Mankind*. London: Papermac.

Holst, M., Isaac, L., Boylston, A. and Roberts, C. A. (2001) *Hull Magistrates Court. Draft Skeletal Report on the Human Skeletal Remains*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Holt, R. D. (1991) "Food and Drinks at Four Daily Time Intervals in a Group of Young Children" *British Dental Journal* **170**, pp 137-143.

Hooke, D. (1988) "Introduction: Later Anglo-Saxon England" in Hooke, D. (ed) *Anglo-Saxon Settlements*. Oxford: Basil Blackwell, pp 1-8.

Horden, P. (1992) "Disease, Dragons and Saints: the Management of Epidemics in the Dark Ages" in Ranger, T. and Slack, P. (eds) *Epidemics and Ideas. Essays on the Historical Perception of Pestilence*. Cambridge: Cambridge University Press, pp 45-76.

Horrox, R. (1999) "Purgatory, Prayer and Plague: 1150-1380" in Jupp, P. C. and Gittings, C. (eds) *Death in England: An Illustrated History*. Manchester: Manchester University Press, pp 90-118.

Howard-Jones, N. (1977) "Fracastoro and Henle: A Re-Appraisal of their Contribution to the Concept of Communicable Diseases" *Medical History* **21**, pp 61-68.

Howe, G. M. (1997) *People, Environment, Disease and Death. A Medical Geography of Britain Throughout the Ages*. Cardiff: University of Wales Press.

Howe, G. M. and Phillips, D. R. (1983) "Medical Geography in the United Kingdom, 1945-1982" in McGlashan, N. D. and Blunden, J. R. (eds) *Geographical Aspects of Health: Essays in Honour of Andrew Learmonth*. London: Academic Press, pp 33-52.

Huggins, P. J. (1978) "Excavation of Belgic and Romano-British Farm with Middle Saxon Cemetery and Churches at Nazeingbury, Essex, 1975-6" *Essex Archaeology and History* **10**, pp 29-117.

Humphreys, J., Ryland, J. W., Barnard, E. A. B., Wellstood, F. C. and Barnett, T. G. (1922-23) "An Anglo-Saxon Cemtery at Bidford-on-Avon, Warwickshire" *Archaeologia* **73**, pp 89-116.

Humphreys, J., Ryland, J. W., Wellstood, F. C., Barnard, E. A. B. and Barnett, T. G. (1923-24) "An Anglo-Saxon Cemetery at Bidford-on-Avon, Warwickshire: Second Report on the Excavations" *Archaeologia* **74**, pp 271-288.

Hunn, A., Lawson, J. and Farley, M. (1994) "The Anglo-Saxon Cemetery at Dinton, Buckinghamshire" in Filmer-Sankey, W. and Griffiths, D. (eds) *Anglo-Saxon Studies in Archaeology and History.* **7**. Oxford: The Oxford University Committee for Archaeology, pp 85-148.

Hunter, J., Ralston, I. and Hamlin, A. (1993) "The Structure of British Archaeology" in Hunter, J. and Ralston, I. (eds) *Archaeological Resource Management in the UK: An Introduction.* Stroud: Alan Sutton Publishing Ltd, pp 30-43.

Huntley, J. P. and Stallibrass, S. (1995) *Plant and Vertebrate Remains from Archaeological Sites in Northern England: Data Reviews and Future Directions. Architectural and Archaeological Society of Durham and Northumberland Research Report No. 4* Durham: Architectural and Archaeological Society of Durham and Northumberland.

Hutchinson, D. L., Larsen, C. S., Schoeninger, M. J. and Norr, L. (1998) "Regional Variation in the Pattern of Maize Adoption and Use in Florida and Georgia" *American Antiquity* **63**, pp 397-416.

Hutchinson, P. (1966) "The Anglo-Saxon Cemetery at Little Eriswell, Suffolk" *Proceedings of the Cambridge Antiquarian Society* **59**, pp 1-32.

Irigoyen, M. E. and Sánchez-Hinojosa, G. (2000) "Changes in Dental Caries Prevalence in 12-Year-Old Students in the State of Mexico after 9 Years of Salt Fluoridation" *Caries Research* **34**, pp 303-307.

İşcan, M. Y. and Loth, S. R. (1986) "Determination of Age from the Sternal Rib in White Females: A Test of the Phase Method" *Journal of Forensic Sciences* **31**, pp 990-999.

Ismail, A. I., Tanzer, J. M. and Dingle, J. L. (1997) "Current Trends of Sugar Consumption in Developing Countries" *Community Dentistry and Oral Epidemiology* **25**, pp 438-443.

Jackson, D., James, P. M. C. and Wolfe, W. B. (1975) "Fluoridation in Anglesey. A Clinical Study" *British Dental Journal* **138**, pp 165-171.

Jakob, B. (2004) *Prevalence and Patterns of Disease in Early Medieval Populations: A Comparison of Skeletal Samples from Fifth to Eighth Century AD Britain and Germany.* Durham: Unpublished PhD Thesis, University of Durham.

Janaway, R. C. (1996) "The Decay of Buried Human Remains and their Associated Materials" in Hunter, J., Roberts, C. A. and Martin, A. (eds) *Studies in Crime: An Introduction to Forensic Archaeology.* London: BT Batsford Ltd, pp 58-85.

Janaway, R. C., Wilson, A. S., Caffell, A. C. and Roberts, C. A. (2001) "Human Skeletal Collections: The Responsibilities of Project Managers, Physical Anthropologists, Conservators and the Need for Standardized Condition Assessments" in Williams, E. (ed) *Human Remains: Conservation, Retrieval and Analysis. British Archaeological Reports, International Series,* **934**. Proceedings of a conference held in Williamsburg, VA, Nov 7-11th 1999: Oxford; Archaeopress, pp 199-208.

Jarcho, S. (1970) "Yellow Fever, Cholera, and the Beginnings of Medical Cartography" *Journal of the History of Medicine and Allied Sciences* **26**, pp 131-142.

Jenkins, V. and Rogers, J. (1993) "Human Bone" in Graham, A. H. and Davies, S. M. (eds) *Excavations in the Town Centre of Trowbridge, Wiltshire 1977 and 1986-88. Wessex Archaeology Report* **2**. Salisbury: Trust for Wessex Archaeology Ltd, pp 120-127.

Jensen, M. E. (1999) "Diet and Dental Caries" *Dental Clinics of North America* **43**, pp 615-633.

Johnson, S. (1983) *Burgh Castle: Excavations by Charles Green, 1958-61. East Anglian Archaeology* **20**. Dereham: Norfolk Archaeological Unit.

Jones, A. K. G. (1986) "Fish Bone Survival in the Digestive Systems of the Pig, Dog and Man: Some Experiments" in Brinkhuizen, D. C. and Clason, A. T. (eds) *Fish and Archaeology: Studies in Osteometery, Taphonomy, Seasonality and Fishing Methods. British Archaeological Reports, International Series,* **294**. Oxford; BAR, pp 53-61.

Jones, K. and Moon, G. (1987) *Health, Disease and Society: An Introduction to Medical Geography*. London and New York: Routledge and Kegan Paul.

Jordanova, L. J. (1979) "Earth Science and Environmental Medicine: the Synthesis of the Late Enlightenment" in Jordanova, L. J. and Porter, R. S. (eds) *Images of the Earth. Essays in the History of the Environmental Sciences. BSHS Monographs* Chalfont St. Giles: British Society for the History of Science, pp 119-146.

Julshamn, K., Malde, M. K., Bjorvatn, K. and Krogedal, P. (2004) "Fluoride Retention of Atlantic Salmon (*Salmo salar*) Fed Krill Meal" *Aquaculture Nutrition* **10**, pp 9-13.

Kashket, S. and DePaola, D. P. (2002) "Cheese Consumption and the Development and Progression of Dental Caries" *Nutrition Reviews* **60**, pp 97-103.

Kearns, R. A. and Gesler, W. M. (1998) "Introduction" in Kearns, R. A. and Gesler, W. M. (eds) *Putting Health into Place. Landscape, Identity and Well-being.* Syracuse, New York: Syracuse University Press, pp 1-13.

Kearns, R. A. and Joseph, A. E. (1993) "Space in its Place: Developing the Link in Medical Geography" *Social Science and Medicine* **37**, pp 711-717.

Kelly, M., Steele, J., Nuttall, N., Bradnock, G., Morris, J., Nunn, J., Pine, C., Pitts, N., Treasure, E. and White, D. (2000) *Adult Dental Health Survey. Oral Health in the United Kingdom, 1998.* London: The Stationery Office.

Kemp, R. (1996) *Anglian Settlement at 46-54 Fishergate. The Archaeology of York: Anglian York* **7/1**. York: Council for British Archaeology.

Kerr, N. W. (1986) "Dental Examination of the Aberdeen Carmelite Collection. Late Medieval 1300-1600" in Cruwys, E. and Foley, R. A. (eds) *Teeth and Anthropology. British Archaeological Reports, International Series* **291**. Oxford; BAR, pp 189-199.

Kerr, N. W. (1990) "The Prevalence and Pattern of Distribution of Root Caries in a Scottish Medieval Population" *Journal of Dental Research* **69**, pp 857-860.

Kerr, N. W., Bruce, M. F. and Cross, J. F. (1990) "Caries Experience in Medieval Scots" *American Journal of Physical Anthropology* **83**, pp 69-76.

Key, C. A., Aiello, L. C. and Molleson, T. (1994) "Cranial Suture Closure and Its Implications for Age Estimation" *International Journal of Osteoarchaeology* **4**, pp 193-207.

Kimura, T., Morita, M., Kinoshita, T., Tsuneishi, M., Akagi, T., Yamashita, F. and Watanabe, T. (2001) "Fluoride Intake from Food and Drink in Japanese Children Aged 1-6 Years" *Caries Research* **35**, pp 47-49.

Kinsley, A. G. (1993) *Broughton Lodge. Excavations on the Romano-British Settlement and Anglo-Saxon Cemetery at Broughton Lodge, Willoughby-on-the-Wolds, Nottinghamshire, 1964-8. Nottingham Archaeological Monographs* **4**. Nottingham: Department of Classical and Archaeological Studies (Archaeology Section), University of Nottingham.

Knowles, D. D. (1961) *The Religious Orders in England. Volume 2: The End of the Middle Ages*. Cambridge: Cambridge University Press.

Knowles, D. D. (1962) *The Religious Orders in Enland. Volume 1*. Cambridge: Cambridge University Press.

Knox, E. G. (1985) *Fluoridation of Water and Cancer: A Review of the Epidemiological Evidence*. London: HMSO.

König, K. G. (2000) "Diet and Oral Health" *International Dental Journal* **50**, pp 162-174.

Künzel, W. and Fischer, T. (1997) "Rise and Fall of Caries Prevalence in German Towns with Different F Concentrations in Drinking Water" *Caries Research* **31**, pp 166-173.

Künzel, W. and Fischer, T. (2000) "Caries Prevalence after Cessation of Water Fluoration in La Salud, Cuba" *Caries Research* **34**, pp 20-25.

La Corte, D. M. and McMillan, D. J. (2004) *Regular Life: Monastic, Canonical and Mendicant Rules*. Kalamazoo, Michigan: Medieval Institute Publications.

Labarge, M. W. (2003) *Mistress, Maids and Men: Baronial Life in the Thirteenth Century*. London: Phoenix.

Langston, J. (1996) "Analysis of the Human Skeletal Material" (pp 93-99) in Hall, R. A. and Whyman, M. (eds) Settlement and Monasticism at Ripon, North Yorkshire, From the 7th to 11th Centuries AD. *Medieval Archaeology* **40**, pp 62-150.

Larsen, C. S. (1995) "Biological Changes in Human Populations with Agriculture" *Annual Review of Anthropology* **24**, pp 185-213.

Larsen, C. S. (2000) *Skeletons in Our Closet: Recording Our Past Through Bioarchaeology*. Princeton and Oxford: Princeton University Press.

Larsen, C. S., Schoeninger, M. J., van der Merwe, N. J., Moore, K. M. and Lee-Thorp, J. A. (1992) "Carbon and Nitrogen Stable Isotopic Signatures of Human Dietary Change in the Georgia Bight" *American Journal of Physical Anthropology* **89**, pp 197-214.

Lawless, G. (1987) *Augustine of Hippo and his Monastic Rule*. Oxford: Clarendon Press.

Leach, P. (1984) *The Archaeology of Taunton: Excavations and Fieldwork to 1980. Western Archaeological Trust Excavation Monograph* **8**. Gloucester: Alan Sutton Publishing.

Learmonth, A. (1988) *Disease Ecology*. Oxford: Basil Blackwell.

Lebret, E. (1995) "Indicators of Public Health and Environmental Quality" in de Lepper, M. J. C., Scholten, H. J. and Stern, R. M. (eds) *The Added Value of Geographical Information Systems in Public and Environmental Health*. Dordrecht: Kluwer Academic Publishers, pp 25-39.

Lee, F. (2001) *Hospital of St James and St Mary Magdalene, Chichester. Draft Report on the Human Skeletal Remains*. University of Bradford: Unpublished.

Lee, F. (no date-a) *The Human Bone Report from the Anglo-Saxon Cemetery at Tanners Row, Pontefract, West Yorkshire*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Lee, F. (no date-b) *The Pathological Report on Selected Skeletons from the Anglo-Saxon Levels at York Minster*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Lee, J., Wolch, J. R. and Walsh, J. (1998) "Homeless Health and Service Needs" in Kearns, R. A. and Gesler, W. M. (eds) *Putting Health into Place. Landscape, Identity and Well-being*. Syracuse, New York: Syracuse University Press, pp 120-142.

Lennon, M. A. (2000) "Water Fluoridation: A Test of the Government's Public Health Credentials" *Community Dental Health* **17**, pp 210-211.

Levine, R. S. (2001) "Caries Experience and Bedtime Consumption of Sugar-Sweetened Food and Drinks - A Survey of 600 Children" *Community Dental Health* **18**, pp 228-231.

Lewis, M. E. (2002) "Impact of Industrialization: Comparative Study of Child Health in Four Sites from Medieval and Postmedieval England (A.D. 850-1859)" *American Journal of Physical Anthropology* **119**, pp 211-223.

Lilley, J. M., Stroud, G., Brothwell, D. R. and Williamson, M. H. (eds) (1994) *The Jewish Burial Ground at Jewbury. The Archaeology of York: The Medieval Cemeteries* **12**. York: Council for British Archaeology for York Archaeological Trust.

Lindsay, W. J. (1989) "Linlithgow. The Burials" in Stones, J. A. (ed) *Three Scottish Carmelite Friaries: Excavations at Aberdeen, Linlithgow and Perth 1980-1986. Monograph Series* **6**. Edinburgh: Society of Antiquaries of Scotland, pp Microfiche 1:B12-D5.

Lingström, P. and Borrman, H. (1999) "Distribution of Dental Caries in an Early 17th Century Swedish Population with Special Reference to Diet" *International Journal of Osteoarchaeology* **9**, pp 395-403.

Lingström, P., Holm, A.-K., Mejàre, I., Twetman, S., Söder, B., Norlund, A., Axelsson, S., Lagerlöf, F., Nordenram, G., Petersson, L. G., Dahlgren, H. and Källestål, C. (2003) "Dietary Factors in the Prevention of Dental Caries: A Systematic Review" *Acta Odontologica Scandinavica* **61**, pp 331-340.

Littleton, J. (1999) "Palaeopathology of Skeletal Fluorosis" *American Journal of Physical Anthropology* **109**, pp 465-483.

Littleton, J. and Frohlich, B. (1993) "Fish-Eaters and Farmers: Dental Pathology in the Arabian Gulf" *American Journal of Physical Anthropology* **92**, pp 427-447.

Lloyd, O. L. (1995) "The Exploration of the Possible Relationship between Deaths, Births and Air Pollution in Scottish Towns" in de Lepper, M. J. C., Scholten, H. J. and Stern, R. M. (eds) *The Added Value of Geographical Information Systems in Public and Environmental Health*. Dordrecht: Kluwer Academic Publishers, pp 167-180.

Lonie, I. M. (1977) "A Structural Pattern in Greek Dietetics and the Early History of Greek Medicine" *Medical History* **21**, pp 235-260.

Lorimer, D. H. (1992) "The Skeletons from Four Winds" (pp 205-206) in Dalland, M. (ed) Long Cist Burials at Four Winds, Longniddry, East Lothian. *Proceedings of the Society of Antiquaries of Scotland* **122**, pp 197-206.

Losee, F. L. and Adkins, B. L. (1969) "A Study of the Mineral Environment of Caries-Resistant Navy Recruits" *Caries Research* **3**, pp 23-31.

Losee, F. L. and Ludwig, T. G. (1970) "Trace Elements and Caries" *Journal of Dental Research Supplement* **49**, pp 1229-1235.

Loth, S. R. and İşcan, M. Y. (1989) "Morphological Assessment of Age in the Adult: The Thoracic Region" in Iscan, M. (ed) *Age Markers in the Human Skeleton*. Springfield: Thomas, pp 105-135.

Lovejoy, C. O., Meindl, R. S., Mensforth, R. P. and Barton, T. J. (1985) "Multifactorial Determination of Skeletal Age at Death: A Method and Blind Tests of Its Accuracy" *American Journal of Physical Anthropology* **68**, pp 1-14.

Lovell, N. C. (2000) "Paleopathological Description and Diagnosis" in Katzenberg, M. A. and Saunders, S. R. (eds) *Biological Anthropology of the Human Skeleton*. New York: Wiley-Liss, pp 217-248.

Lucy, S. (1994) "Children in Early Medieval Cemeteries" *Archaeological Review from Cambridge* **13**, pp 35-33.

Lucy, S. (2000) *The Anglo-Saxon Way of Death*. Stroud: Sutton Publishing.

Ludwig, T. G. and Bibby, B. G. (1969) "Geographic Variations in the Prevalence of Dental Caries in the United States of America" *Caries Research* **3**, pp 32-43.

Lukacs, J. R. (1992) "Dental Paleopathology and Agricultural Intensification in South Asia: New Evidence From Bronze Age Harappa" *American Journal of Physical Anthropology* **87**, pp 133-150.

Lukacs, J. R. (1995) "The 'Caries Correction Factor': a New Method of Calibrating Dental Caries Rates to Compensate for Antemortem Loss of Teeth" *International Journal of Osteoarchaeology* **5**, pp 151-156.

Lunt, D. A. (1986) "Mediaeval Dentitions from St. Andrews" in Foley, R. A. and Cruwys, E. (eds) *Teeth and Anthropology. British Archaeological Reports, International Series,* **291**. Oxford; BAR, pp 215-224.

Lunt, D. A. and Watt, M. E. (1997) "The Human Dentitions" in Hill, P. (ed) *Whithorn and St Ninian. The Excavation of a Monastic Town, 1984-91.* Stroud: Sutton Publishing, pp 562-592.

Lunt, D. A. and Young, A. (1996) "Dental and Anatomical Reports" (pp 424-434) in Proudfoot, E. (ed) Excavations at the Long Cist Cemetery on the Hallow Hill, St Andrews, Fife, 1975-7. *Proceedings of the Society of Antiquaries of Scotland* **126**, pp 387-454.

Luoma, H., Ranta, H. and Turtola, L. (1971) "The Potassium and Phosphorous Content of a Cariogenic Streptococcus Modified by Fluoride and Selenium" *Caries Research* **5**, pp 96-99.

Madrigal, L. (1995) *Statistics for Anthropology.* Cambridge: Cambridge University Press.

Magilton, J. and Lee, F. (1989) "The Leper Hospital of St James and St Mary Magdalene, Chichester" in Roberts, C. A., Lee, F. and Bintliff, J. (eds) *Burial Archaeology: Current Research, Methods and Developments. British Archaeological Reports, British Series,* **211**. Oxford; BAR, pp 15-37.

Magilton, J. R. (1980) *The Church of St Helen-on-the-Walls, Aldwark. The Archaeology of York: The Medieval Walled City north-east of the Ouse* **10/1**. York: Council for British Archaeology for York Archaeological Trust.

Malim, T. and Hines, J. (1998) *The Anglo-Saxon Cemetery at Edix Hill (Barrington A), Cambridgeshire. CBA Research Report* **112**. York: Council for British Archaeology.

Manchester, K. (1987) "Skeletal Evidence for Health and Disease" in Boddington, A., Garland, A. N. and Janaway, R. C. (eds) *Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science.* Manchester: Manchester University Press, pp 163-179.

Marlow, C. A. (1992) "Human Bone from 1989" (pp 215-220) in Scull, C. (ed) Excavation and Survey at Watchfield, Oxfordshire, 1983-92. *The Archaeological Journal* **149**, pp 124-281.

Marlow, M. (1986) "Report on the Human Teeth" (pp 299) in Daniels, R. (ed) The Excavation of the Church of the Franciscans, Hartlepool, Cleveland. *Archaeological Journal* **143**, pp 291-298.

Marlow, M. and Birkett, D. (1992) "The Human Remains: The Population, Skeletal Pathology" in Sherlock, S. J. and Welch, M. G. (eds) *An Anglo-Saxon Cemetery at Norton, Cleveland. CBA Research Report* **82**. London: Council for British Archaeology, pp 107-119.

Marsh, P. D. (1999) "Microbiolgic Aspects of Dental Plaque" *Dental Clinics of North America* **43**, pp 599-614.

Marthaler, T. M. (1990) "Changes in the Prevalence of Dental Caries: How Much Can Be Attributed to Changes in Diet?" *Caries Research, Supplement* **24**, pp 3-15.

Marthaler, T. M., Brunelle, J., Downer, M. C., König, K. G., Truin, G. J., Künzel, W., O'Mullane, D. M., Møller, I. J., von der Fehr, F. R. and Vrbic, V. (1996) "The Prevalence of Dental Caries in Europe 1990-1995" *Caries Research* **30**, pp 237-255.

Martin, E., Plouviez, J. and Ross, H. (1984) "Archaeology in Suffolk 1983" *Proceedings of the Suffolk Institute of Archaeology and History* **35**, pp 321-328.

Massagrande, F. (1995) "Using GIS with Non-Systematic Survey Data: the Mediterranean Evidence" in Lock, G. R. and Stancic, Z. (eds) *Archaeology and Geographical Information Systems: A European Perspective*. London: Taylor and Francis, pp 55-65.

May, J. (1950) "Medical Geography: Its Methods and Objectives" *The Geographical Review* **40**, pp 9-41.

Mayer, J. D. (2000) "Geography, Ecology and Emerging Infectious Diseases" *Social Science and Medicine* **50**, pp 937-952.

Mays, S. A. (1989) *The Anglo-Saxon Human Bone from School Street, Ipswich, Suffolk*. Ancient Monuments Laboratory Report 115/89, English Heritage: Unpublished.

Mays, S. A. (1991) *The Mediaeval Burials from the Blackfriars Friary, School Street, Ipswich, Suffolk (Excavated 1983-85)*. Ancient Monuments Laboratory Report 117/87, English Heritage: Unpublished.

Mays, S. A. (1996) "The Human Skeletal Remains" in Timby, J. R. (ed) *The Anglo-Saxon Cemetery at Empingham II, Rutland. Excavations Carried Out Between 1974 and 1975. Oxbow Monograph* **70**. Oxford: Oxbow Books, pp 21-33.

Mays, S. A. (1997) "Carbon Stable Isotope Ratios in Medieval and Later Human Skeletons from Northern England" *Journal of Archaeological Science* **24**, pp 561-567.

Mays, S. A. (1997) "A Perspective on Human Osteoarchaeology in Britain" *International Journal of Osteoarchaeology* **7**, pp 600-604.

Mays, S. A. (1998) *The Archaeology of Human Bones*. London & New York: Routledge.

Mays, S. A. (2004) "After the Bone Report: the Long-Term Fate of Skeletal Collections" in Brickley, M. and McKinley, J. I. (eds) *Guidelines to the Standards for Recording Human Remains. Institute of Field Archaeologists Paper No.* **7**. Southampton and Reading: British Association of Biological Anthropology and Osteoarchaeology and the Institute of Field Archaeologists, pp 46-47.

Mays, S. A., Fysh, E. and Taylor, G. M. (2002) "Investigation of the Link Between Visceral Surface Rib Lesions and Tuberculosis in a Medieval Skeletal Series from England Using Ancient DNA" *American Journal of Physical Anthropology* **119**, pp 27-36.

Mays, S. A., Taylor, G. M., Legge, A. J., Young, D. B. and Turner-Walker, G. (2001) "Paleopathological and Biomolecular Study of Tuberculosis in a Medieval Skeletal Collection from England" *American Journal of Physical Anthropology* **114**, pp 298-311.

Mazengo, M. C., Söderling, E., Alakuijala, P., Tiekso, J., Tenovuo, J., Simell, O. and Hausen, H. (1994) "Flow Rate and Composition of Whole Saliva in Rural and Urban Tanzania with Special Reference to Diet, Age, and Gender" *Caries Research* **28**, pp 468-476.

McCarthy, M. R. (1990) *A Roman, Anglian and Medieval Site at Blackfriars Street, Carlisle: Excavations 1977-9. Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **4**. Kendal: Cumberland and Westmorland Antiquarian and Archaeological Society.

McKendry, M. (1973) *Seven Hundred Years of English Cooking*. London: Treasure Press.

McKinley, J. I. (1996) "The Human Bone" (pp 76-87) in Wymer, J. J. (ed) The Excavation of a Ring-Ditch at South Acre. *Barrow Excavations in Norfolk, 1984-88* **77**, Dereham: Field Archaeology Division, Norfolk Museums Service, pp 58-89.

McKinley, J. I. (1998) "Human Skeletal Remains" in Penn, K. (ed) *An Anglo-Saxon Cemetery at Oxborough, West Norfolk: Excavations in 1990. East Anglian Archaeology Occasional Papers* **5**. Dereham: Field Archaeology Division, Norfolk Museums Service, pp 19-23.

McNeill, W. H. (1994) *Plagues and Peoples*. London: Penguin Books.

Meade, M. S. and Earickson, R. J. (2000) *Medical Geography*. New York and London: The Guilford Press.

Meindl, R. S., Lovejoy, C. O., Mensforth, R. P. and Don Carlos, L. (1985a) "Accuracy and Direction of Error in the Sexing of the Skeleton: Implications for Paleodemography" *American Journal of Physical Anthropology* **68**, pp 79-85.

Meindl, R. S., Lovejoy, C. O., Mensforth, R. P. and Walker, R. A. (1985b) "A Revised Method of Age Determination Using the Os Pubis, with a Review and Tests of Accuracy of Other Current Methods of Pubic Symphyseal Aging" *American Journal of Physical Anthropology* **68**, pp 29-45.

Mertes, K. (1988) *The English Noble Household 1250-1600: Good Governance and Politic Rule*. Oxford: Basil Blackwell.

Messer, E. (1989) "Small but Healthy? Some Cultural Considerations" *Human Organization* **48**, pp 39-52.

Metcalf, P. and Huntington, R. (1991) *Celebrations of Death: The Anthropology of Mortuary Ritual*. Cambridge: Cambridge University Press.

Meyer-Lueckel, H., Satzinger, T. and Kielbassa, A. M. (2002) "Caries Prevalence Among 6- to 16-Year-Old Students in Jamaica 12 Years After the Introduction of Salt Fluoridation" *Caries Research* **36**, pp 170-173.

Miles, A. E. W. (1989) *An Early Christian Chapel and Burial Ground on the Isle of Ensay, Outer Hebrides, Scotland, with a Study of the Skeletal Remains. British Archaeological Reports, British Series,* **212**. Oxford: BAR.

Miller, E., Ragsdale, B. D. and Ortner, D. J. (1996) "Accuracy in Dry Bone Diagnosis: a Comment on Palaeopathological Methods" *International Journal of Osteoarchaeology* **6**, pp 221-229.

Milne, N. (1990) "Sexing of Human Hip Bones" *Journal of Anatomy* **172**, pp 221-226.

Ministry of Agriculture, Fisheries and Food (1994) *The Dietary and Nutritional Survey of British Adults - Further Analysis.* London: HMSO.

Møller-Christensen, V. (1967) "Evidence of Leprosy in Earlier Peoples" in Brothwell, D. and Sandison, A. T. (eds) *Diseases in Antiquity. A Survey of the Diseases, Injuries and Surgery of Early Populations.* Springfield, Illinois: Charles C Thomas, pp 295-306.

Molleson, T. (1995) "Rates of Ageing in the Eighteenth Century" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies.* Toronto: Canadian Scholars' Press Inc., pp 199-222.

Molleson, T. I. and Cox, M. J. (1993) *The Spitalfields Project Volume 2: The Anthropology of the Middling Sort. CBA Research Report* **86**. York: Council for British Archaeology.

Moore, W. J. and Corbett, M. E. (1971) "The Distribution of Dental Caries in Ancient British Populations I. Anglo-Saxon Period" *Caries Research* **5**, pp 151-168.

Moore, W. J. and Corbett, M. E. (1973) "The Distribution of Dental Caries in Ancient British Populations II. Iron Age, Romano-British and Mediaeval Periods" *Caries Research* **7**, pp 139-153.

Moore, W. J. and Corbett, M. E. (1975) "Distribution of Dental Caries in Ancient British Populations III. The 17th Century" *Caries Research* **9**, pp 163-175.

Morgan, P. (1999) "Of Worms and War: 1380-1558" in Jupp, P. C. and Gittings, C. (eds) *Death in England: An Illustrated History.* Manchester: Manchester University Press, pp 119-146.

Moynihan, P. (2003) "Diet and Dental Caries" in Murray, J. J., Nunn, J. H. and Steele, J. G. (eds) *The Prevention of Oral Disease.* Oxford: Oxford University Press, pp 9-34.

Moynihan, P. J., Ferrier, S. and Jenkins, G. N. (1999) "The Cariostatic Potential of Cheese: Cooked Cheese-Containing Meals Increase Plaque Calcium Concentration" *British Dental Journal* **187**, pp 664-667.

Murphy, M. (1998) "Feeding Medieval Cities: Some Historical Approaches" in Carlin, M. and Rosenthal, J. T. (eds) *Food and Eating in Medieval Europe.* London: The Hambledon Press, pp 117-131.

Murray, K. A. and Murray, T. (1991) "A Test of the Auricular Surface Aging Technique" *Journal of Forensic Sciences* **36**, pp 1162-1169.

Nash, C. E. (2000) "Aquatic Animals" in Kiple, K. F. and Ornelas, K. C. (eds) *The Cambridge World History of Food.* **1**. Cambridge: Cambridge University Press, pp 456-467.

Nelson, G. C., Lukacs, J. R. and Yule, P. (1999) "Dates, Caries, and Early Tooth Loss During the Iron Age of Oman" *American Journal of Physical Anthropology* **108**, pp 333-343.

Nenk, B. S., Margeson, S. and Hurley, M. (1994) "Medieval Britain and Ireland in 1993" *Medieval Archaeology: Journal of the Society for Medieval Archaeology* **38**, pp 184-293.

Nielsen, F. H. (2000) "Other Trace Elements" in Kiple, K. F. and Ornelas, K. C. (eds) *The Cambridge World History of Food*. **1**. Cambridge: Cambridge University Press, pp 856-868.

Nixon, G. S. and Myers, V. B. (1970) "Estimation of Selenium in Human Dental Enamel by Activation Analysis" *Caries Research* **4**, pp 179-187.

Norton, S. and Boylston, A. (1997) *Binchester Roman Fort, County Durham. Report on the Human Skeletal Remains*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Numbers, R. L. (2000) "Medical Science before Scientific Medicine: Reflections on the History of Medical Geography" in Rupke, N. A. (ed) *Medical Geography in Historical Perspective (Medical History Supplement No. 20)*. London: The Wellcome Trust Centre for the History of Medicine at UCL, pp 217-220.

Nutton, V. (1983) "The Seeds of Disease: An Explanation of Contagion and Infection from the Greeks to the Renaissance" *Medical History* **27**, pp 1-34.

Nutton, V. (1993) "Humoralism" in Bynum, W. F. and Porter, R. (eds) *Companion Encyclopedia of the History of Medicine*. **1**. London and New York: Routledge, pp 281-291.

Nutton, V. (1995a) "Medicine in Late Antiquity and the Early Middle Ages" in Conrad, L. I., Neve, M., Nutton, V., Porter, R. and Wear, A. (eds) *The Western Medical Tradition: 800 BC to AD 1800*. Cambridge: Cambridge University Press, pp 71-87.

Nutton, V. (1995b) "Medicine in Medieval Western Europe, 1000-1500" in Conrad, L. I., Neve, M., Nutton, V., Porter, R. and Wear, A. (eds) *The Western Medical Tradition: 800 BC to AD 1800*. Cambridge: Cambridge University Press, pp 139-205.

Nutton, V. (1995c) "Medicine in the Greek World, 800-50 BC" in Conrad, L. I., Neve, M., Nutton, V., Porter, R. and Wear, A. (eds) *The Western Medical Tradition: 800 BC to AD 1800*. Cambridge: Cambridge University Press, pp 11-38.

Nutton, V. (1995d) "Roman Medicine, 250 BC to AD 200" in Conrad, L. I., Neve, M., Nutton, V., Porter, R. and Wear, A. (eds) *The Western Medical Tradition: 800 BC to AD 1800*. Cambridge: Cambridge University Press, pp 39-70.

O'Connor, T. P. (1991) *Bones from 46-54 Fishergate. The Archaeology of York: The Animal Bones* **15/14**. London: Council for British Archaeology.

O'Connor, T. P. (1993) "The Human Skeletal Material" in Rodwell, W. J. and Rodwell, K. A. (eds) *Rivenhall: Investigations of a Roman Villa, Church and Village, 1950-1977: Volume 2 - Specialist Studies. CBA Research Report* **80**. London: Council for British Archaeology, pp 96-102.

Okullo, I., Nordrehaug, Å., Haugejorden, O. and Rwenyonyi, C. M. (2003) "Variation in Caries Experience and Sugar Intake Among Secondary School Students in Urban and Rural Uganda" *Acta Odontologica Scandinavica* **61**, pp 197-202.

Ortner, D. J. (1991) "Theoretical and Methodological Issues in Paleopathology" in Ortner, D. J. and Aufderheide, A. C. (eds) *Human Palaeopathology: Current Synthesis and Future Options*. Washington D.C.: Smithsonian Institution Press, pp 5-11.

Ortner, D. J. (1994) "Descriptive Methodology in Paleopathology" in Owsley, D. W. and Jantz, R. L. (eds) *Skeletal Biology in the Great Plains: Migration, Warfare, Health, and Subsistence*. Washington & London: Smithsonian Institution Press, pp 73-80.

Ortner, D. J. (1998) "Male-Female Immune Reactivity and Its Implications for Interpreting Evidence in Human Skeletal Paleopathology" in Grauer, A. L. and Stuart-Macadam, P. (eds) *Sex and Gender in Paleopathological Perspective*. Cambridge: Cambridge University Press, pp 79-92.

Ortner, D. J. (2001) "Disease Ecology" in Brothwell, D. R. and Pollard, A. M. (eds) *Handbook of Archaeological Sciences*. Chichester: John Wiley & Sons Ltd., pp 225-235.

Ortner, D. J. (2003) *Identification of Palaeopathological Disorders in Human Skeletal Remains*. Amsterdam and San Diego: Academic Press.

Ortner, D. J., Tuross, N. and Stix, A. I. (1992) "New Approaches to the Study of Disease in Archaeological New World Populations" *Human Biology* **64**, pp 337-360.

O'Sullivan, E. A., Williams, S. A. and Curzon, M. E. J. (1992) "Dental Caries in Relation to Nutritional Stress in Early English Child Populations" *Pediatric Dentistry* **14**, pp 26-29.

O'Sullivan, E. A., Williams, S. A., Wakefield, R. C., Cape, J. E. and Curzon, M. E. J. (1993) "Prevalence and Site Characteristics of Dental Caries in Primary Molar Teeth from Prehistoric Times to the 18th Century in England" *Caries Research* **27**, pp 147-153.

Owen, T. and Pilbeam, E. (1992) *Ordnance Survey: Map Makers to Britain since 1791*. London: HMSO.

Owsley, D. W., Orser, C. E., Mann, R. W., Moore-Jansen, P. H. and Montgomery, R. L. (1987) "Demography and Pathology of an Urban Slave Population from New Orleans" *American Journal of Physical Anthropology* **74**, pp 185-197.

Parfitt, K. and Brugmann, B. (1997) *The Anglo-Saxon Cemetery on Mill Hill, Deal, Kent. The Society for Medieval Archaeology Monograph Series* **14**. London: The Society for Medieval Archaeology.

Parry, A. and de Waal, E. (1990) *The Rule of St Benedict*. Leominster: Gracewing.

Pate, F. D. (1994) "Bone Chemistry and Palaeodiet" *Journal of Archaeological Method and Theory* **1**, pp 161-207.

Pechenkina, E. A., Benfer, R. A., Jr, and Zhijun, W. (2002) "Diet and Health Changes at the End of the Chinese Neolithic: The Yangshao/Longshan Transition in Shaanxi Province" *American Journal of Physical Anthropology* **117**, pp 15-36.

Pelling, M. (1978) *Cholera, Fever and English Medicine 1825-1865*. Oxford: Oxford University Press.

Pelling, M. (1993) "Contagion/Germ Theory/Specificity" in Bynum, W. F. and Porter, R. (eds) *Companion Encyclopedia of the History of Medicine.* **1**. London and New York: Routledge, pp 309-334.

Penn, K. (1998) *An Anglo-Saxon Cemetery at Oxborough, West Norfolk: Excavations in 1990. East Anglian Archaeology Occasional Papers* **5**. Dereham: Field Archaeology Division, Norfolk Museums Service.

Perkins, C. R. and Parry, R. B. (1996) *Mapping the UK.* London: Bowker-Saur.

Pickstone, J. V. (1992) "Dearth, Dirt and Fever Epidemics: Rewriting the History of British 'Public Health', 1780-1850" in Ranger, T. and Slack, P. (eds) *Epidemics and Ideas. Essays on the Historical Perception of Pestilence.* Cambridge: Cambridge Universtiy Press, pp 125-148.

Porter, R. (1999) *The Greatest Benefit to Mankind: A Medical History of Humanity from Antiquity to the Present.* London: Fontana Press.

Powell, F. (1996) "The Human Remains" in Boddington, A. (ed) *Raunds Furnells: The Anglo-Saxon Church and Churchyard.* London: English Heritage, pp 113-124.

Power, C. (1993) "Reconstructing Patterns of Health and Dietary Change in Irish Prehistoric Populations" *Ulster Journal of Archaeology* **56**, pp 9-17.

Powers, R. (1962) "The Disparity Between Known Age and Age as Estimated by Cranial Suture Closure" *Man* **62**, pp 52-54.

Powers, R. and Cullen, R. (1987) "The Human Skeletal Remains" in Evison, V. I. (ed) *Dover: The Buckland Anglo-Saxon Cemetery.* London: Historic Buildings and Monuments Commission for England, pp 197-201.

Price, R. and Ponsford, M. (1998) *St Bartholomew's Hospital, Bristol. The Excavation of a Medieval Hospital: 1976-8. CBA Research Report* **110**. York: Council for British Archaeology.

Privat, K. L. and O'Connell, T. C. (2002) "Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire: Dietary and Social Implications" *Journal of Archaeological Science* **29**, pp 779-790.

Proudfoot, E. (1996) "Excavations at the Long Cist Cemetery on the Hallow Hill, St Andrews, Fife, 1975-7" *Proceedings of the Society of Antiquaries of Scotland* **126**, pp 387-454.

Pullan, B. (1992) "Plague and Perceptions of the Poor in Early Modern Italy" in Ranger, T. and Slack, P. (eds) *Epidemics and Ideas. Essays on the Historical Perception of Pestilence.* Cambridge: Cambridge University Press, pp 101-123.

Putnam, G. (1978) "Analysis of the Skeletal Material" (pp 54-63) in Huggins, P. J. (ed) Excavation of Belgic and Romano-British Farm with Middle Saxon Cemetery and Churches at Nazeingbury, Essex, 1975-6. *Essex Archaeology and History* **10**, pp 29-117.

Rackham, O. (2000) *The History of the Countryside: The Classic History of Britain's Landscape, Flora and Fauna.* London: Phoenix Press.

Ralston, I. and Hunter, J. (1999) "British Archaeology Since the End of the Second World War" in Hunter, J. and Ralston, I. (eds) *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution*. New York: Routledge, pp 1-12.

Rebelo Viera, J. M., Rebelo, M. A. B. and Cury, J. A. (2002) "Evaluation of the Cariogenic Potential of Cassava Flours from the Amazonian Region" *Caries Research* **36**, pp 417-422.

Redfern, R. (2004) "The Spitalfields Market Project" *British Association for Biological Anthropology and Osteoarchaeology: Annual Review 2003* **5**, pp 7.

Reed, M. (1990) *The Landscape of Britain from the Beginnings to 1914*. London: Routledge.

Richards, J. D. (1999) "The Scandinavian Presence" in Hunter, J. and Ralston, I. (eds) *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution*. New York: Routledge, pp 194-209.

Ritchie, J. N. G. (1981) "Excavations at Machrins, Colonsay" *Proceedings of the Society of Antiquaries of Scotland* **111**, pp 263-281.

Roberts, C. A. (2000) "Infectious Disease in Biocultural Perspective: Past, Present and Future Work in Britain" in Cox, M. and Mays, S. (eds) *Human Osteology in Archaeology and Forensic Science*. London: Greenwich Medical Media Ltd., pp 145-162.

Roberts, C. A. and Connell, B. (2004) "Guidance on Recording Palaeopathology" in Brickley, M. and McKinley, J. I. (eds) *Guidelines to the Standards for Recording Human Remains. Institute of Field Archaeologists Paper No. 7*. Southampton and Reading: British Association of Biological Anthropology and Osteoarchaeology and the Institute of Field Archaeologists, pp 34-39.

Roberts, C. A. and Cox, M. (2003) *Health and Disease in Britain: From Prehistory to the Present Day*. Stroud: Sutton.

Roberts, C. A., Lewis, M. E. and Boocock, P. A. (1998) "Infectious Disease, Sex, and Gender: The Complexity of It All" in Grauer, A. L. and Stuart-Macadam, P. (eds) *Sex and Gender in Paleopathological Perspective*. Cambridge: Cambridge University Press, pp 93-113.

Roberts, C. A. and Manchester, K. (1995) *The Archaeology of Disease*. Stroud: Alan Sutton Publishing Limited.

Robinson, A. H. (1982) *Early Thematic Mapping in the History of Cartography*. Chicago and London: University of Chicago Press.

Rodwell, W. J. and Rodwell, K. A. (1985) *Rivenhall: Investigations of a Villa, Church and Village, 1950-1977. Chelmsford Archaeological Trust Report 4* Chelmsford and London: Chelmsford Archaeological Trust and Council for British Archaeology.

Rogers, J. (1984) "Skeletons from the Lay Cemetery at Taunton Priory" in Leach, P. (ed) *The Archaeology of Taunton: Excavations and Fieldwork to 1980. Western Archaeological Trust Excavation Monograph* **8**. Gloucester: Alan Sutton Publishing, pp 194-200.

Rogers, J. (1999) "Burials: The Human Skeletons" in Heighway, C. and Bryant, R. (eds) *The Golden Minster. The Anglo-Saxon Minster and Later Medieval Priory of St Oswald at Gloucester. CBA Research Report* **117**. York: Council for British Archaeology, pp 229-246.

Rogers, J. and Waldron, T. (1995) *A Field Guide to Joint Disease in Archaeology*. Chester: Wiley.

Rogers, J. and Waldron, T. (2001) "DISH and the Monastic Way of Life" *International Journal of Osteoarchaeology* **11**, pp 357-365.

Rogers, J., Watt, I. and Dieppe, P. (1981) "Arthritis in Saxon and Medieval Skeletons" *British Medical Journal* **283**, pp 1668-1670.

Rose, J. C., Burnett, B. A. and Harmon, A. M. (1991) "Disease and Ecology in the Lower Mississippi Valley and the Trans-Mississippi South" *International Journal of Osteoarchaeology* **1**, pp 241-245.

Rosen, G. (1953) "Leonhard Ludwig Finke and the First Medical Geography" in Underwood, E. A. (ed) *Science, Medicine and History: Written in Honor of C. Singer*. London: Oxford University Press, pp 186-193.

Rosen, G. (1993) *A History of Public Health*. Baltimore & London: John Hopkins University Press.

Roundy, R. W., Roundy, L. M. and Nawalinski, T. (1983) "Scale in the Relationship between Behaviour and Disease" in McGlashan, N. D. and Blunden, J. R. (eds) *Geographical Aspects of Health: Essays in Honour of Andrew Learmonth*. London: Academic Press, pp 257-272.

Rugg-Gunn, A. J. (2001) "Nutrition, Diet and Oral Health" *Journal of the Royal College of Surgeons of Edinburgh* **46**, pp 320-328.

Ruottinen, S., Karjalainen, S., Pienihäkkinen, K., Lagström, H., Niinikoski, H., Salminen, M., Rönnemaa, T. and Simell, O. (2004) "Sucrose Intake since Infancy and Dental Health in 10-Year-Old Children" *Caries Research* **38**, pp 142-148.

Rupke, N. A. (1996) "Humboldtian Medicine" *Medical History* **40**, pp 293-310.

Rupke, N. A. and Wonders, K. E. (2000) "Humboldtian Representations in Medical Cartography" in Rupke, N. A. (ed) *Medical Geography in Historical Perspective (Medical History Supplement No. 20)*. London: The Wellcome Trust Centre for the History of Medicine at UCL, pp 163-175.

Sakashita, R., Inoue, M., Inoue, N., Pan, Q. and Zhu, H. (1997) "Dental Disease in the Chinese Yin-Shang Period with Respect to Relationships Between Citizens and Slaves" *American Journal of Physical Anthropology* **103**, pp 401-408.

Salvolini, E., Di Giorgio, R., Curatola, A., Mazzanti, L. and Fratto, G. (1998) "Biochemical Modifications of Human Whole Saliva Induced by Pregnancy" *British Journal of Obstetrics and Gynaecology* **105**, pp 656-660.

Saunders, S. R., de Vito, C. and Katzenberg, M. A. (1997) "Dental Caries in Nineteenth Century Upper Canada" *American Journal of Physical Anthropology* **104**, pp 71-87.

Saunders, S. R., Herring, A., Shawchuck, L. A. and Boyce, G. (1995a) "The Nineteenth-Century Cemetery at St. Thomas' Anglian Church, Belleville: Skeletal Remains, Parish Records and Censuses" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies*. Toronto: Canadian Scholars' Press Inc, pp 93-117.

Saunders, S. R., Herring, D. A. and Boyce, G. (1995b) "Can Skeletal Samples Accurately Represent the Living Populations They Come From? The St. Thomas' Cemetery Site, Belleville, Ontario" in Grauer, A. L. (ed) *Bodies of Evidence: Reconstructing History Through Skeletal Analysis*. New York: Wiley Liss, pp 69-89.

Sayegh, A., Dini, E. L., Holt, R. D. and Bedi, R. (2002) "Food and Drink Consumption, Sociodemographic Factors and Dental Caries in 4-5-Year-Old Children in Amman, Jordan" *British Dental Journal* **193**, pp 37-42.

Scheuer, J. L. and Bowman, J. E. (1995) "Correlation of Documentary and Skeletal Evidence in the St. Bride's Crypt Population" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies*. Toronto: Canadian Scholars' Press Inc., pp 49-70.

Schulte, A. G., Gräber, R., Kasperk, C., Koch, M. J. and Staehle, H. J. (2002) "Influence of Fluoridated Salt on Urinary Fluoride Excretion in Adults" *Caries Research* **36**, pp 391-397.

Schwartz, J. H. (1995) *Skeleton Keys: An Introduction to Human Skeletal Morphology, Development, and Analysis*. Oxford: Oxford University Press.

Scull, C. (1992) "Excavation and Survey at Watchfield, Oxfordshire, 1983-92" *The Archaeological Journal* **149**, pp 124-281.

Seppä, L., Hausen, H., Kärkkäinen, S. and Larmas, M. (2002) "Caries Occurrence in a Fluoridated and Nonfluoridated Town in Finland. A Retrospective Study Using Longitadinal Data from Public Dental Records" *Caries Research* **36**, pp 308-314.

Shapter, T. (1971) *The History of the Cholera in Exeter in 1832*. Wakefield and London: SR Publishers Ltd.

Shaw, R. (1994) "The Anglo-Saxon Cemetery at Eccles: A Preliminary Report" *Archaeologia Cantiana* **114**, pp 165-188.

Shennan, S. (1997) *Quantifying Archaeology*. Edinburgh: Edinburgh University Press.

Sherlock, S. J. and Welch, M. G. (1992) *An Anglo-Saxon Cemetery at Norton, Cleveland. CBA Research Report* **82**. York: Council for British Archaeology.

Silva, M. F. d. A., Jenkins, G. N., Burgess, R. C. and Sandham, H. J. (1986) "Effects of Cheese on Experimental Caries in Human Subjects" *Caries Research* **20**, pp 263-269.

Silverstone, L. (1990) "Dental Caries" in Elderton, R. J. (ed) *Clinical Dentistry in Health and Disease: The Dentition and Dental Care*. Oxford: Heinemann Medical Books, pp 214-236.

Silvester, R. (1999) "Medieval Reclamation of Marsh and Fen" in Cook, H. and Williamson, T. (eds) *Water Management in the English Landscape: Field, Marsh and Meadow*. Edinburgh: Edinburgh University Press, pp 122-140.

Slack, P. (1992) "Introduction" in Ranger, T. and Slack, P. (eds) *Epidemics and Ideas: Essays on the Historical Perception of Pestilence*. Cambridge: Cambridge University Press, pp 1-20.

Slater, P. J. (2001) "Patterns of Access to Public Oral Health Care in Queensland by Gender, Indigenous Status and Rurality" *Australian Dental Journal* **46**, pp 122-133.

Spriggs, J. A. (1989) "On and Off-Site Conservation of Bone" in Roberts, C. A., Lee, F. and Bintliff, J. (eds) *Burial Archaeology. Current Research, Methods and Developments. British Archaeological Reports, British Series,* **211**. Oxford; BAR, pp 39-45.

Sreenby, L. M. (1983) "Cereal Availability and Dental Caries" *Community Dentistry and Oral Epidemiology* **11**, pp 148-155.

Start, H. and Kirk, L. (1998) "'The Bodies of Friends' - The Osteological Analysis of a Quaker Burial Ground" in Cox, M. (ed) *Grave Concerns: Death and Burial in England 1700-1850. CBA Research Report* **113**. York: Council for British Archaeology, pp 167-177.

Steane, J. M. and Foreman, M. (1988) "Medieval Fishing Tackle" in Aston, M. (ed) *Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports, British Series,* **182(i)**. Oxford; BAR, pp 137-186.

Steckel, R. H. and Rose, J. C. (eds) (2002a) *The Backbone of History: Health and Nutrition in the Western Hemisphere*. Cambridge: Cambridge University Press.

Steckel, R. H. and Rose, J. C. (2002b) "Introduction" in Steckel, R. H. and Rose, J. C. (eds) *The Backbone of History: Health and Nutrition in the Western Hemisphere*. Cambridge: Cambridge University Press, pp 3-8.

Stecksén-Blicks, C., Sunnegårdh, K. and Borssén, E. (2004) "Caries Experience and Background Factors in 4-Year-Old Children: Time Trends 1967-2002" *Caries Research* **38**, pp 149-155.

Steele, J. G. (2004) "Association News: British Association for Biological Anthropology and Osteoarchaeology Annual Report" *British Association for Biological Anthropology and Osteoarchaeology: Annual Review 2003* **5**, pp 3-4.

Sten, S. (1995) "Trading with Fish in Medieval Sweden. Some Examples from Archaeological Bone Finds" *Archaeofauna* **4**, pp 65-69.

Stern, R. M. (1995) "Environment and Health Data in Europe as a Tool for Risk Management: Needs, Uses and Strategies" in de Lepper, M. J. C., Scholten, H. J. and Stern, R. M. (eds) *The Added Value of Geographical Information Systems in Public and Environmental Health*. Dordrecht: Kluwer Academic Publishers, pp 3-24.

Stevenson, L. G. (1965) "Putting Disease on the Map: The Early Use of Spot Maps in the Study of Yellow Fever" *Journal of the History of Medicine and Allied Sciences* **20**, pp 226-261.

Stirland, A. (1985) "The Human Bones" in Ayers, B. (ed) *Excavation within the North-East Bailey of Norwich Castle, 1979. East Anglian Archaeology Report* **28**. Dereham: Norfolk Archaeological Unit, pp 49-57.

Stones, J. A. (1989a) "The Burials at Aberdeen, Linlithgow and Perth Friaries" in Stones, J. A. (ed) *Three Scottish Carmelite Friaries: Excavations at Aberdeen, Linlithgow and Perth 1980-1986. Monograph Series* **6**. Edinburgh: Society of Antiquaries of Scotland, pp 111-116.

Stones, J. A. (ed) (1989b) *Three Scottish Carmelite Friaries: Excavations at Aberdeen, Linlithgow and Perth 1980-1986. Monograph Series* **6**. Edinburgh: Society of Antiquaries of Scotland.

Storey, R., Morfin, L. M. and Smith, V. (2002) "Social Disruption and the Maya Civilization of Mesoamerica" in Steckel, R. H. and Rose, J. C. (eds) *The Backbone of History: Health and Nutrition in the Western Hemisphere*. Cambridge: Cambridge University Press, pp 283-306.

Stroud, G. (1989) "The Processing of Human Bone from Archaeological Sites" in Roberts, C. A., Lee, F. and Bintliff, J. (eds) *Burial Archaeology. Current Research, Methods & Developments. British Archaeological Reports, British Series* **211**. Oxford; BAR, pp 47-49.

Stroud, G. (1993) "Human Skeletal Material" in Dallas, C. (ed) *Excavations in Thetford by B. K. Davison between 1964 and 1970. East Anglian Archaeology* **62**. Dereham: Field Archaeology Division, Norfolk Museums Service, pp 168-176.

Stroud, G. (1994) "The Population" in Lilley, J. M., Stroud, G., Brothwell, D. R. and Williamson, M. H. (eds) *The Jewish Burial Ground at Jewbury. The Archaeology of York: The Medieval Cemeteries* **12**. York: Council for British Archaeology for York Archaeological Trust, pp 424-521.

Stroud, G. (1998) "Human Bone" in Price, R. and Ponsford, M. (eds) *St Bartholomew's Hospital, Bristol. The Excavation of a Medieval Hospital: 1976-8. CBA Research Report* **110**. York: Council for British Archaeology, pp 175-181.

Stroud, G. and Kemp, R. L. (1993) *Cemeteries of the Church and Priory of St Andrew, Fishergate. The Archaeology of York: The Medieval Cemeteries* **12/2**. York: Council for British Archaeology for York Archaeological Trust.

Stuart-Macadam, P. (1986) "Health and Disease in the Monks of Stratford Langthorne Abbey" *Essex Journal* **21**, pp 67-71.

Stuart-Macadam, P. L. (1991) "Anaemia in Roman Britain: Poundbury Camp" in Bush, H. and Zvelebil, M. (eds) *Health in Past Societies: Biocultural Interpretations of Human Skeletal Remains in Archaeological Contexts. British Archaeological Reports, International Series,* **567**. Oxford; BAR, pp 101-113.

Sutter, R. C. (1995) "Dental Pathologies Among Inmates of the Monroe County Poorhouse" in Grauer, A. L. (ed) *Bodies of Evidence: Reconstructing History Through Skeletal Analysis*. New York: Wiley Liss, pp 185-196.

Swabey, F. (1998) "The Household of Alice de Bryene, 1412-13" in Carlin, M. and Rosenthal, J. T. (eds) *Food and Eating in Medieval Europe*. London: The Hambledon Press, pp 133-144.

Takahashi, L. M. (1998) "Concepts of Difference in Community Health" in Kearns, R. A. and Gesler, W. M. (eds) *Putting Health into Place. Landscape, Identity and Well-being*. Syracuse, New York: Syracuse University Press, pp 143-167.

Talbot, C. H. (1967) *Medicine in Medieval England*. London: Oldbourne.

Tayles, N., Domett, K. and Nelsen, K. (2000) "Agriculture and Dental Caries? The Case of Rice in Prehistoric Southeast Asia" *World Archaeology* **32**, pp 68-83.

Taylor, A., Duhig, C. and Hines, J. (1997) "An Anglo-Saxon Cemetery at Oakington, Cambridgeshire" *Proceedings of the Cambridge Antiquarian Society* **86**, pp 57-90.

Thomas, C., Sloane, B. and Phillpotts, C. (1997) *Excavations at the Priory and Hospital of St. Mary Spital, London. MoLAS Monograph* **1**. London: MoLAS.

Thomas, F. D., Kassab, J. Y. and Jones, B. M. (1995) "Fluoridation in Anglesey 1993: a Clinical Study of Dental Caries in 5-Year-Old Children Who Had Experienced Sub-optimal Fluoridation" *British Dental Journal* **178**, pp 55-59.

Thomas, R. (1993) "English Heritage Funding Policies and their Impact on Research Strategy" in Hunter, J. and Ralston, I. (eds) *Archaeological Resource Management in the UK: An Introduction*. Stroud: Alan Sutton Publishing Ltd, pp 136-148.

Thomas, R. W. (1990) "Introduction: Issues in Spatial Epidemiology" in Thomas, R. W. (ed) *Spatial Epidemiology*. London: Pion, pp 1-14.

Thomas, R. W. (1992) *Geomedical Systems: Intervention and Control*. London: Routledge.

Timby, J. R. (1996) *The Anglo-Saxon Cemetery at Empingham II, Rutland. Excavations Carried Out Between 1974 and 1975. Oxbow Monograph* **70**. Oxford: Oxbow Books.

Trotter, M. (1970) "Estimation of Stature from Intact Long Limb Bones" in Stewart, T. D. (ed) *Personal Identification in Mass Disasters*. Washington DC: National Museum of Natural History, Smithsonian Institution, pp 71-83.

Trotter, M. and Gleser, G. C. (1952) "Estimation of Stature from Long Limb Bones of American Whites and Negros" *American Journal of Physical Anthropology* **10**, pp 463-514.

Trotter, M. and Gleser, G. C. (1958) "A Re-Evaluation of Estimation of Stature Based on Measurements of Stature Taken During Life and of Long Bones After Death" *American Journal of Physical Anthropology* **16**, pp 79-123.

Turner, C. G., II (1979) "Dental Anthropological Indications of Agriculture Among the Jomon People of Central Japan" *American Journal of Physical Anthropology* **51**, pp 619-636.

Ubelaker, D. H. (1989) *Human Skeletal Remains: Excavation, Analysis, Interpretation*. Washington: Taraxacum Press.

Ubelaker, D. H. (1995) "Osteological and Archival Evidence for Disease in Historic Quito, Ecuador" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies*. Toronto: Canadian Scholars' Press Inc., pp 223-239.

Valencius, C. B. (2000) "Histories of Medical Geography" in Rupke, N. A. (ed) *Medical Geography in Historical Perspective (Medical History Supplement No. 20)*. London: The Wellcome Trust Centre for the History of Medicine at UCL, pp 3-28.

van Neer, W. and Ervynck, A. (1996) "Food Rules and Status: Patterns of Fish Consumption in a Monastic Community (Ename, Belgium)" *Archaeofauna* **5**, pp 155-164.

Verhagen, P., McGlade, J., Gili, S. and Risch, R. (1995) "Some Criteria for Modelling Socio-Economic Activities in the Bronze Age of South-East Spain" in Lock, G. R. and Stancic, Z. (eds) *Archaeology and Geographical Information Systems: A European Perspective.* London: Taylor and Francis, pp 187-209.

Verhasselt, Y. (1993) "Geography of Health: Some Trends and Perspectives" *Social Science and Medicine* **36**, pp 119-123.

Visser, M. (1991) *The Rituals of Dinner.* New York: Grove Weidenfeld.

Wade-Martins, P. (1980) *Excavations in North Elmham Park, 1967-1972. East Anglian Archaeology* **9**. Gressenhall: Norfolk Archaeological Unit.

Waldron, T. (1987a) *The Human Bones from Brighton Hill South.* Ancient Monuments Laboratory Report 117/87, English Heritage: Unpublished.

Waldron, T. (1987b) "Relative Survival of the Human Skeleton: Implications for Palaeopathology." in Boddington, A., Garland, A. N. and Janaway, R. C. (eds) *Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science.* Manchester: Manchester University Press, pp 55-64.

Waldron, T. (1991) "Rates for the Job: Measures of Disease Frequency in Palaeopathology" *International Journal of Osteoarchaeology* **1**, pp 17-25.

Waldron, T. (1993) *The Human Remains from the Royal Mint Site.* MoLSS, London: Unpublished Report HUM/REP/07/93.

Waldron, T. (1994a) *Counting the Dead.* Chichester: John Wiley & Sons.

Waldron, T. (1994b) "The Human Bones: General Discussion" (pp 125-127) in Hunn, A., Lawson, J. and Farley, M. (eds) The Anglo-Saxon Cemetery at Dinton, Buckinghamshire. *Anglo-Saxon Studies in Archaeology and History* **7**, Oxford: Oxford University Committee for Archaeology, pp 85-148.

Waldron, T. (1994c) "The Human Remains" in Evison, V. I. (ed) *An Anglo-Saxon Cemetery at Great Chesterford, Essex. CBA Research Report* **91**. York: Council for British Archaeology, pp 52-66.

Walker, P. L. (1986) "Dental Evidence for Prehistoric Dietary Change on the Northern Channel Islands, California" *American Antiquity* **51**, pp 375-383.

Walker, P. L. (1995) "Problems of Preservation and Sexism in Sexing: Some Lessons from Historical Collections for Palaeodemographers" in Saunders, S. R. and Herring, A. (eds) *Grave Reflections: Portraying the Past through Cemetery Studies.* Toronto: Canadian Scholars' Press Inc., pp 31-47.

Walker, P. L. (2000) "Bioarchaeological Ethics: A Historical Perspective on the Value of Human Remains" in Katzenberg, M. A. and Saunders, S. R. (eds) *Biological Anthropology of the Human Skeleton.* New York: Wiley-Liss, pp 3-39.

Walker, P. L., Dean, G. and Shapiro, P. (1991) "Estimating Age From Tooth Wear in Archaeological Populations" in Kelley, M. A. and Larsen, C. S. (eds) *Advances in Dental Anthropology.* New York: Wiley-Liss Inc., pp 169-178.

Ward, S. W. (1990) "Burials from the Dominican Friary" in Ward, S. W. (ed) *Excavations at Chester: The Lesser Medieval Religious Houses. Sites Investigated 1964-1983.* **6**. Chester: Department of Leisure Services, Chester City Council, pp 120-126.

Warren, J. J. and Levy, S. M. (1999) "Systemic Fluoride: Sources, Amounts, and Effects of Ingestion" *Dental Clinics of North America* **43**, pp 695-711.

Watts, L. and Leach, P. (1996) *Henley Wood, Temples and Cemetery. Excavations 1962-69 by the late Earnest Greenfield and Others. CBA Research Report* **99**. York: Council for British Archaeology.

Wear, A. (1995) "Medicine in Early Modern Europe, 1500-1700" in Conrad, L. I., Neve, M., Nutton, V., Porter, R. and Wear, A. (eds) *The Western Medical Tradition: 800BC to AD1800.* Cambridge: Cambridge University Press, pp 215-340.

Webb, J. S., Thornton, I. and Fletcher, K. (1966) "Seleniferous Soils in Parts of England and Wales" *Nature* **211**, pp 327.

Webster, L. E. and Cherry, J. (1972) "Medieval Britain in 1971" *Medieval Archaeology: Journal of the Society for Medieval Archaeology* **16**, pp 147-212.

Welander, R. D. E., Batey, C. and Cowie, T. G. (1987) "A Viking Burial from Kneep, Uig, Isle of Lewis" *Proceedings of the Society of Antiquaries of Scotland* **117**, pp 149-174.

Wells, C. (1964) *Bones, Bodies and Disease: Evidence of Disease and Abnormality in Early Man.* London: Thames and Hudson.

Wells, C. (1966) "Report on the Human Remains from Little Eriswell" (pp 21-28) in Hutchinson, P. (ed) The Anglo-Saxon Cemetery at Little Eriswell, Suffolk. *Proceedings of the Cambridge Antiquarian Society* **59**, pp 1-32.

Wells, C. (1967a) "Pseudopathology" in Brothwell, D. and Sandison, A. T. (eds) *Diseases in Antiquity. A Survey of the Diseases, Injuries and Surgery of Early Populations.* Springfield, Illinois: Charles C Thomas, pp 5-19.

Wells, C. (1967b) "Report on the Human Skeletons from Red Castle, Thetford" *Norfolk Archaeology* **34**, pp 155-186.

Wells, C. (1988) "Appendix 3: An Early Medieval Case of Death in Childbirth" in White, W. (ed) *Skeletal Remains from the Cemetery of St Nicholas Shambles, City of London.* London: the London and Middlesex Archaeological Society, pp 71-73.

Wells, C. (1996) "Human Burials" in Evison, V. I. and Hill, P. (eds) *Two Anglo-Saxon Cemeteries at Beckford, Hereford and Worcester. CBA Research Report* **103**. York: Council for British Archaeology, pp 41-62.

Wells, C. (2000) "The Human Remains of Jarrow Abbey" *Paleobios* **12**, pp 15-53.

Wells, C. and Cayton, H. (1980) "The Human Bones" in Wade-Martins, P. (ed) *Excavations in North Elmham Park, 1967-1972. East Anglian Archaeology* **9**. Gressenhall: Norfolk Archaeological Unit, pp 247-302.

Wells, C., Grainger, G., Denston, B. and Chadwick Hawkes, S. (2003) "The Inhumations and Cremations" in Chadwick Hawkes, S. and Grainger, G. (eds) *The Anglo-Saxon Cemetery at Worthy Park, Kingsworthy, near Winchester, Hampshire. Oxford School of Archaeology Monograph* **59**. Oxford: Oxford School of Archaeology, pp 153-188.

West, B. (1990) "Human Bones" in Ward, S. W. (ed) *Excavations at Chester: The Lesser Medieval Religious Houses. Sites Investigated 1964-1983. Grosvenor Museum Archaeological Excavation and Survey Reports* **6**. Chester: Department of Leisure Services, Chester City Council, pp 127-137.

Westlake, A. (1995) "Strategies for the Use of Geography in Epidemiological Analysis" in de Lepper, M. J. C., Scholten, H. J. and Stern, R. M. (eds) *The Added Value of Geographical Information Systems in Public and Environmental Health*. Dordrecht: Kluwer Academic Publishers, pp 135-144.

White, B. (1999) *Human Skeletal Remains from St. Mary, Stratford Langthorne*. MoLSS, London: Unpublished Report HUM/REP/01/99.

White, W. (1988) *Skeletal Remains from the Cemetery of St Nicholas Shambles, City of London*. London: London and Middlesex Archaeological Society.

Wiggins, R., Boylston, A. and Roberts, C. A. (1993) *Report on the Human Skeletal Remains from Blackfriars, Gloucester (19/91)*. Calvin Wells Laboratory, University of Bradford: Unpublished.

Wiggins, R., Boylston, A. and Roberts, C. A. (1998) "Full Report on the Human Osteology" in Drinkall, G. and Foreman, M. (eds) *The Anglo-Saxon Cemetery at Castledyke South, Barton-on-Humber. Sheffield Excavation Reports* **6**. Sheffield: Sheffield Academic Press Ltd, pp MF1 D7-G14; MF2 A2-A11.

Wilkinson, L. (1993) "Epidemiology" in Bynum, W. F. and Porter, R. (eds) *Companion Encyclopedia of the History of Medicine*. **2**. London and New York: Routledge, pp 1262-1282.

Williams, S. A. and Curzon, M. E. J. (1986) "Observations on Dental Caries in Primary Teeth in some Medieval British Skull Material" in Foley, R. A. and Cruwys, E. (eds) *Teeth and Anthropology. British Archaeological Reports, International Series,* **Vol. 291**. Oxford; BAR, pp 201-213.

Williamson, T. (1988) "Settlement Chronology and Regional Landscapes: The Evidence from the Claylands of East Anglia and Essex" in Hooke, D. (ed) *Anglo-Saxon Settlements*. Oxford: Basil Blackwell, pp 153-175.

Wilmott, T. (1987) "Pontefract" *Current Archaeology* **9**, pp 340-344.

Wing, E. S. (2000) "Animals Used for Food in the Past: As Seen by Their Remains Excavated from Archaeological Sites" in Kiple, K. F. and Ornelas, K. C. (eds) *The Cambridge World History of Food*. **1**. Cambridge: Cambridge University Press, pp 51-58.

Wohl, A. S. (1984) *Endangered Lives: Public Health in Victorian Britain*. London: Methuen & Co. Ltd.

Wood, J. W., Milner, G. R., Harpending, H. C. and Weiss, K. M. (1992) "The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples" *Current Anthropology* **33**, pp 343-370.

Woodward, M. and Walker, A. R. P. (1994) "Sugar Consumption and Dental Caries: Evidence from 90 Countries" *British Dental Journal* **176**, pp 297-302.

World Health Organization (1994) *Fluorides and Oral Health. WHO Technical Report Series* **846**. Geneva: WHO.

Wu, C. D., Darout, I. A. and Skaug, N. (2001) "Chewing Sticks: Timeless Natural Toothbrushes for Oral Cleansing" *Journal of Periodontal Research* **36**, pp 275-284.

Wymer, J. J. (1996) "The Excavation of a Ring-Ditch at South Acre" in Wymer, J. J. (ed) *Barrow Excavations in Norfolk, 1984-88. East Anglian Archaeology* **77**. Dereham: Field Archaeology Division, Norfolk Museums Service, pp 58-89.

Youngs, S. M., Clark, J. and Barry, T. (1986) "Medieval Britain and Ireland in 1985" *Medieval Archaeology: Journal of the Society for Medieval Archaeology* **30**, pp 114-198.

Youngs, S. M., Clark, J. and Barry, T. (1987) "Medieval Britain and Ireland in 1986" *Medieval Archaeology: Journal of the Society for Medieval Archaeology* **31**, pp 110-191.

Zero, D. T. (1999) "Dental Caries Process" *Dental Clinics of North America* **43**, pp 635-664.

APPENDICES

Appendix 1 : Alphabetical list of all Data-sets / Sites used in study (7 pages).

Includes:

- Site Name,
- Location (town/county),
- Data-set/site identification number,
- Medieval Period – Early – Middle –Late,
- Approximate date range – Centuries (Cs),
- Number of skeletons recovered,
- 12-figure grid reference (with supplied grid reference in parentheses),
- References to the skeletal and site reports.

Alphabetical list of all Data-sets / Sites used in study					
Site Name Location	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
Aberdeen Carmelite Friary 12 Martin's Lane, Aberdeen	80	LATE (14 17 Cs)	120	394100 806000 (NJ 941 060)	(Cross and Bruce, 1989) (Kerr, 1986) (Stones, 1989a) (Stones, 1989b)
Addingham West Yorkshire	1	EARLY (8-10 Cs)	83	408460 449740 (SE 0846 4974)	(Boylston and Roberts, 1996) (Adams, 1996)
Ailcy Hill Ripon, West Yorkshire	2	EARLY (6-10 Cs)	27	431710 471140	(Langston, 1996) (Hall and Whyman, 1996)
Apple Down Compton, West Sussex	3	EARLY (5-7 Cs)	126	479430 115090 (SU 7943 1509)	(Harman, 1990) (Down and Welch, 1990)
Beckford A Hereford and Worcester	4	EARLY (5-6 Cs)	24	396400 235500 (964 355)	(Wells, 1996) (Evison and Hill, 1996)
Beckford B Hereford and Worcester	5	EARLY (5-6 Cs)	108	396900 235500 (964 355)	(Wells, 1996) (Evison and Hill, 1996)
Berinsfield Wally Corner gravel pit, Berinsfield, Oxfordshire	6	EARLY (5-7 Cs)	114	458050 195650 (SU 5805 9565)	(Harman, 1995) (Boyle, *et al.*, 1995)
Bidford-on-Avon Warwickshire	7	EARLY (?)	170	410500 251500	(Brash, 1922-23) (Brash, 1923-24) (Humphreys, *et al.*, 1922-23) (Humphreys, *et al.*, 1923-24)
Binchester County Durham	8	EARLY (7-11 Cs)	45	420500 531500	(Norton and Boylston, 1997)
Blackfriars C Carlisle	60	LATE (13-16 Cs)	214	340030 555800 (NY 4003 5580)	(Henderson, 1990) (McCarthy, 1990)
Blackfriars G Ladybellegate Street, Gloucetser	59	LATE (13-16 Cs)	129	383500 218500	(Wiggins, *et al.*, 1993)
Blackfriars I *(See also School Street)* School Street, Ipswich, Suffolk	79	LATE (13-16 Cs)	250	616500 244500	(Mays, 1991) (Martin, *et al.*, 1984)
Blackgate The Keep, Blackgate, Newcastle-upon-Tyne	52	MIDDLE (8-12 Cs)	227	425500 564500	(Boulter and Rega, 1993)
Brighton Hill South Hampshire	78	LATE (?)	52	460600 148900	(Waldron, 1987a) (Youngs, *et al.*, 1987)
Broughton Lodge Willoughby-on-the-Wolds	9	EARLY (5-7 Cs)	80	464800 325000 (SK 648 250)	(Harman, 1993) (Kinsley, 1993)
Buckland Dover, Kent	10	EARLY (5-8 Cs)	66	631000 143000 (TR 310 430)	(Powers and Cullen, 1987) (Evison, 1987)
Burgh Castle Norfolk	11	EARLY (7-10 Cs)	197	647400 304500 (TG 474 045)	(Anderson and Birkett, 1993) (Johnson, 1983)

Alphabetical list of all Data-sets / Sites used in study					
Site Name **Location**	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
Butler's Field Lechlade	12	EARLY (5-8 Cs)	222	421160 200140 (SP 2116 0014)	(Harman, 1998) (Boyle, *et al.*, 1998)
Caister-on-Sea Norfolk	13	EARLY (8-11 Cs)	139	651700 312300 (TG 5170 1230)	(Anderson, 1993) (Darling and Gurney, 1993)
Castledyke South Barton-on-Humber	14	EARLY (5-7 Cs)	199	503100 421700 (TA 031 217)	(Boylston, *et al.*, 1998b) (Wiggins, *et al.*, 1998) (Drinkall and Foreman, 1998)
Charlton Plantation Downton, Wiltshire	15	EARLY (5-7 Cs)	43	416700 124900 (SU 167 249)	(Henderson, 1985) (Davies, 1985)
Chelmsford Dominican Priory Essex	54	LATE (13-16 Cs)	138	570500 206500	(Bayley, 1975)
Chevington Chapel near East Chevington, Northumbria	58	LATE (12-18 Cs)	59	424000 598000	(Boylston, *et al.*, 1998a)
Chichester St James & St Mary Magdalene, Chichester	67	LATE (12-17 Cs)	384	486500 104500	(Lee, 2001) (Magilton and Lee, 1989)
Collingbourne Ducis Cadley, Wiltshire	16	EARLY (6-7 Cs)	30	424580 154150 (SU 2458 5415)	(Fielden, 1978) (Gingell, 1978)
Dinton Buckinghamshire	17	EARLY (5-6 Cs)	20	476500 210500	(Waldron, 1994b) (Hunn, *et al.*, 1994)
Eccles Rowe Place Farm, Eccles, Aylesford, Kent	18	EARLY (?)	169	572200 160500	(Boocock, *et al.*, 1995) (Shaw, 1994) (Detsicas, 1966) (Detsicas, 1971) (Detsicas, 1972) (Detsicas, 1973) (Detsicas, 1974) (Detsicas, 1975) (Detsicas, 1976) (Detsicas, 1989)
Edix Hill Barrington parish, Cambridgeshire	19	EARLY (6-7 Cs)	148	539500 249500	(Duhig, 1998) (Malim and Hines, 1998)
Empingham II Rutland (until 1974); now Leicestershire	20	EARLY (5-7 Cs)	150	493600 308200 (SK 936 082)	(Mays, 1996) (Timby, 1996)
Four Winds Longniddry, East Lothian	21	EARLY (5-7 Cs)	8	344240 677000 (NT 4424 7700)	(Lorimer, 1992) (Dalland, 1992)
Franciscan Church, Hartlepool Friar Terrace, Hartlepool, Cleveland	84	LATE (13-16 Cs)	150	452900 533800 (NZ 529338)	(Birkett, 1986) (Marlow, 1986) (Daniels, 1986)
Golden Minster A (9-12thC) St Oswald's Church, Gloucester, Gloucestershire	22	MIDDLE (9-12 Cs)	139	383500 218500	(Rogers, 1999) (Heighway and Bryant, 1999)
Golden Minster B (12-13thC) St Oswald's Church, Gloucester, Gloucestershire	63	LATE (12-13 Cs)	180	383500 218500	(Rogers, 1999) (Heighway and Bryant, 1999)

Alphabetical list of all Data-sets / Sites used in study					
Site Name **Location**	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
Golden Minster C (13-16thC) St Oswald's Church, Gloucester, Gloucestershire	65	LATE (13-16 Cs)	34	383500 218500	(Rogers, 1999) (Heighway and Bryant, 1999)
Great Chesterford Essex	23	EARLY (5-7 Cs)	167	550100 243500 (TL 501 435)	(Waldron, 1994c) (Evison, 1994)
Greyfriars Chester	66	LATE (13-16 Cs)	49	340500 366500	(West, 1990) (Ward, 1990)
Hallow Hill St. Andrews, Fife	24	EARLY (6-9 Cs)	96	349400 715600 (NO 494 156)	(Lunt and Young, 1996) (Proudfoot, 1996)
Henley Wood Yatton, North Somerset	25	EARLY (5-7 Cs)	67	344290 165200 (ST 4429 6520)	(Watts and Leach, 1996)
Holborough Holborough Hill, Kent	26	EARLY (7-8 Cs)	36	570500 162500	(Denston and Noble, 1956) (Evison, 1956)
Holy Trinity Priory London	70	MIDDLE (11-12 Cs)	39	533450 181020 (TQ 3345 8102)	(Downs, 1979) (Conheeney, 1993) (Conheeney, ?date)
Hull Priory Hull Magistrate's Court, Hull	53	LATE (14-16 Cs)	245	509500 429500	(Holst, *et al.*, 2001)
Isle of Ensay Scotland	51	LATE (16-17 Cs)	146	97500 886800 (975 869)	(Miles, 1989)
Jarrow A Newcastle-upon-Tyne Tyne and Wear	86	EARLY (7-9 Cs)	170	433900 565200 (4339 5652)	(Wells, 2000) (Anderson, 1992) (Cramp, 1969) (Webster and Cherry, 1972) (Cramp, 1999) (Cramp, 1976)
Jarrow B Newcastle-upon-Tyne Tyne and Wear	87	LATE (11-16 Cs)	189	433900 565200 (4339 5652)	(Wells, 2000) (Anderson, 1992) (Cramp, 1969) (Webster and Cherry, 1972) (Cramp, 1999) (Cramp, 1976)
Jewbury York	49	LATE (12-13 Cs)	476	460750 452150 (SE 6075 5215)	(Stroud, 1994) (Lilley, *et al.*, 1994)
Kneep Traigh na Berie, Uig, Isle of Lewis	27	MIDDLE (10 Cs)	1	109900 936400 (NB 099 364)	(Harman, 1987) (Welander, *et al.*, 1987)
Linlithgow Carmelite Friary	81	LATE (13-17 Cs)	201	300500 676500 (NT 003765)	(Cross and Bruce, 1989) (Lindsay, 1989) (Stones, 1989a) (Stones, 1989b)
Little Eriswell Lakenheath airfield, near Little Eriswell	28	EARLY (6 Cs)	28	573100 280300 (TL 731 803)	(Wells, 1966) (Hutchinson, 1966)
Machrins west coast of Colonsay	29	EARLY (9 Cs)	1	135790 693300 (NR 3579 9330)	(Harman, 1981) (Ritchie, 1981)

Alphabetical list of all Data-sets / Sites used in study					
Site Name **Location**	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
Mill Hill Deal, Kent	30	EARLY (6 Cs)	77	636310 150740 (TR 3631 5074)	(Anderson and Andrews, 1997) (Parfitt and Brugmann, 1997)
Milton Keynes Village Milton Keynes	57	LATE (?)	65	489500 239500	(Ensor, *et al.*, 1993)
Nazeingbury Nazeing, Essex	31	EARLY (7-9 Cs)	154	538600 206600 (TL 386 066)	(Putnam, 1978) (Huggins, 1978)
North Elmham Park Norfolk	32	MIDDLE (10-11 Cs)	206	598700 321500	(Wells and Cayton, 1980) (Wade-Martins, 1980)
Norton Cleveland	33	EARLY (6-7 Cs)	125	444500 521500	(Marlow and Birkett, 1992) (Sherlock and Welch, 1992)
Norwich Castle North-east Bailey, Norwich Castle, Norwich	34	MIDDLE (11 Cs)	131	623320 308520 (TG 2332 0852)	(Stirland, 1985) (Ayers, 1985)
Oakington Cambridgeshire	35	EARLY (6 Cs)	26	541500 264500	(Taylor, *et al.*, 1997)
Oxborough near Gooderstone, West Norfolk	36	EARLY (6 Cs)	11	576750 303250 (TF 7675 0325)	(McKinley, 1998) (Penn, 1998)
Pennell Street Lincoln, Lincolnshire	56	LATE (11-16 Cs)	74	497500 371500	(Boghi and Boylston, 1997) (Nenk, *et al.*, 1994)
Perth Carmelite Friary Whitefriars Street, Perth	82	LATE (14-17 Cs)	21	310700 723800 (NO 107238)	(Cross and Bruce, 1989) (Stones, 1989a) (Stones, 1989b)
Raunds Furnells Northamptonshire	37	MIDDLE (10-11 Cs)	363	499900 273300	(Powell, 1996) (Boddington, 1996)
Red Castle Thetford, Norfolk	38	MIDDLE (11 Cs)	85	586080 282950 (TL 8608 8295)	(Wells, 1967b)
Rivenhall A Essex	64	EARLY (7-9 Cs)	47	582900 217850 (TL 8290 1785)	(O'Connor, 1993) (Rodwell and Rodwell, 1985)
Rivenhall B Essex	73	MIDDLE (10-12 Cs)	30	582900 217850 (TL 8290 1785)	(O'Connor, 1993) (Rodwell and Rodwell, 1985)
Rivenhall C Essex	83	LATE (12-14 Cs)	38	582900 217850 (TL 8290 1785)	(O'Connor, 1993) (Rodwell and Rodwell, 1985)
Rivenhall D Essex	74	LATE (14-17 Cs)	39	582900 217850 (TL 8290 1785)	(O'Connor, 1993) (Rodwell and Rodwell, 1985)
Royal Mint Royal Mint Street, London	68	LATE (14-16 Cs)	934	533900 180700 (TQ 339 807)	(Waldron, 1993) (Grainger, *et al.*, 1988) (Hawkins, 1990)
School Street (*See also Blackfriars I*) Ipswich, Suffolk	39	MIDDLE (10-11 Cs)	95	616500 244500	(Mays, 1989) (Martin, *et al.*, 1984)

Alphabetical list of all Data-sets / Sites used in study					
Site Name Location	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
South Acre Norfolk	40	EARLY (?)	119	580320 314720 (TF 8032 1472)	(McKinley, 1996) (Wymer, 1996)
Spitalfields Market London	71	LATE (12-16 Cs)	200	533450 181950 (TQ 33450 81950)	(Connell, 2002)
St. Andrew Fishergate P4 46-54 Fishergate, York	61	MIDDLE (11-12 Cs)	131	460650 451150 (SE 6065 5115)	(Stroud and Kemp, 1993) (O'Connor, 1991) (Kemp, 1996)
St. Andrew Fishergate P6 46-54 Fishergate, York	62	LATE (13-16 Cs)	271	460650 451150 (SE 6065 5115)	(Stroud and Kemp, 1993) (O'Connor, 1991) (Kemp, 1996)
St. Bartholomew's Hospital Narrow Lewins Mead, Brist	85	LATE (14-16 Cs)	30	358660 173190 (ST 58667319)	(Stroud, 1998) (Price and Ponsford, 1998)
St. Giles Hospital Brompton Bridge, North Yorkshire	72	LATE (12-15 Cs)	35	420900 499600 (SE 209996)	(Chundun and Roberts, 1995) (Cardwell, 1995)
St. Helen-on-the-Walls Aldwark, York	50	LATE (10-16 Cs)	1037	460660 452120 (SE 6066 5212)	(Dawes and Magilton, 1980)
St. Leonard's Hospital Lincoln Road, Newark, Nottinghamshire	77	LATE (12-17 Cs)	87	480000 354000	(Bishop, 1983)
St. Mary Spital London	48	LATE (12-16 Cs)	126	533450 181950 (TQ 33450 81950)	(Conheeney, 1997) (Conheeney, 1992) (Thomas, *et al.*, 1997)
Stratford Langthorne Abbey St Mary Stratford Langthorne, Essex	69	LATE (12-16 Cs)	647	539020 183400 (TQ 39020 83400)	(White, 1999) (Stuart-Macadam, 1986)
Tanners Row Pontefract, West Yorkshire	41	EARLY (8-10 Cs)	178	445500 421500	(Lee, no date-a) (Youngs, *et al.*, 1986) (Abramson, 1987) (Wilmott, 1987)
Taunton Priory Canon Street, Taunton	76	LATE (12-16 Cs)	162	323050 124770	(Rogers, 1984) (Hinchliffe, 1984) (Leach, 1984)
Thetford Norfolk	42	MIDDLE (11-12 Cs)	81	587050 282310 (TL 8705 8231)	(Stroud, 1993) (Dallas, 1993)
Trowbridge Wiltshire	75	MIDDLE (10-12 Cs)	286	385530 157925	(Jenkins and Rogers, 1993) (Graham and Davies, 1993)
Watchfield Vale of the White Horse, Oxfordshire	43	EARLY (5-7 Cs)	43	424000 190000 (SU 24 90)	(Harman, 1992) (Marlow, 1992) (Scull, 1992)
West Heslerton Cooks Sand Quarry, North Yorkshire	44	EARLY (5-7 Cs)	193	491770 476500 from site map	(Cox, 1999) (Haughton and Powlesland, 1999a) (Haughton and Powlesland, 1999b)
Whithorn A Galloway, Scotland	88	EARLY (6-8 Cs)	53	244500 540500	(Cardy, 1997) (Lunt and Watt, 1997) (Hill, 1997)

Alphabetical list of all Data-sets / Sites used in study					
Site Name Location	**Data-set / Site No.**	**Medieval Period (Date Range)**	**No. of Skeletons Recovered**	**Grid Reference Easting Northing (Supplied)**	**Reference(s) to skeletal and site reports**
Whithorn B Galloway, Scotland	47	LATE (14-15 Cs)	1605	244500 540500	(Cardy, 1997) (Lunt and Watt, 1997) (Hill, 1997)
Worthy Park Kingsworthy, Hampshire	45	EARLY (5-7 Cs)	100	450000 132900 (SU 500329)	(Wells, *et al.*, 2003) (Hawkes and Wells, 1983) (Hawkes and Grainger, 2003)
York Minster York	46	EARLY (?)	66	460300 452100	(Lee, no date-b)
Ysgol Twm o'r Nant Denbigh, Clwyd	55	LATE (?)	170	305500 366500	(Boocock and Roberts, 1994)
No. = Number; **Cs** = Centuries; **?** = Date Range unknown.					

Data Recording Form - Page 1

Site Information

Site Name:

Address: ____________________

Location: ____________________

Date: ____________________ Period: ____________________

Site Type:

Comments: ____________________

____

Date Excavated: ____________________ Osteologist: ____________________

Endnote Refs: ____________________

Number of Skeletons

Females: __________ Subadult: __________

Males: __________ Unaged: __________

Unsexed: __________

Total Adults: __________ **Total Number of Skeletons:** __________

Comments:

Stature

	Minimum	Mean	Maximum	Number
Males:				
Females:				

Formula Used: ____________________

Comments:

Data Recording Form - Page 2

Dental Disease

No. of Individuals Observed:

No. of Males Observed: ________

No. of Females Observed: ________

No. of Teeth Present:

No. of Male Teeth Present: ________

No. of Female Teeth Present: ________

Caries

No. of Individuals with Caries: ________

No. of Males with Caries: ________

No. of Females with Caries:

No. of Teeth with Caries: ________

No. of Male Teeth with Caries: ________

No. of Female Teeth with Caries:

Enamel Hypoplasia

No. of Individuals with EH:

No. of Males with EH: ________

No. of Females with EH: ________

No. of Teeth with EH:

No. of Male Teeth with EH: ________

No. of Female Teeth with EH: ________

Comments:

Neoplastic Disease

Endocrine Disease

Miscellaneous

Paget's Disease

Data Recording Form - Page 3

Infectious Disease

Non-Specific Infection

Specific Infection

Leprosy:

Tuberculosis:

Treponemal:

Joint Disease

Osteoarthritis

DISH

AS

Gout

Rheumatoid Arthritis

Data Recording Form - Page 4

Trauma

Spondylolysis

Metabolic Disease

Cribra Orbitalia

Rickets

Scurvy

Osteoporosis

Congenital Disease

Spina Bifida

Vertebral Anomalies

Cleft Palate

Appendix 3 : All Sites for which data was collected (2 pages).

Medieval Period	**Site Name**	**Data-set / Site No.**	**Prevalence for Teeth From**			
			Teeth	**Skeletons**	**Both**	**Neither**
Early Medieval	Addingham	1	Y			
	Ailcy Hill	2				x
	Apple Down	3	Y			
	Beckford A	4	Y	Y	Y	
	Beckford B	5	Y	Y	Y	
	Berinsfield	6	Y	Y	Y	
	Bidford-on-Avon	7				x
	Binchester	8	Y			
	Broughton Lodge	9	Y	Y	Y	
	Buckland	10	Y	Y	Y	
	Burgh Castle	11	Y	Y	Y	
	Butler's Field	12	Y	Y	Y	
	Caister-on-Sea	13	Y	Y	Y	
	Castledyke South	14	Y	Y	Y	
	Charlton Plantation	15	Y	Y	Y	
	Collingbourne Ducis	16	Y	Y	Y	
	Dinton	17				x
	Eccles	18	Y			
	Edix Hill	19	Y			
	Empingham II	20	Y	Y	Y	
	Four Winds	21	Y			
	Great Chesterford	23				x
	Hallow Hill	24	Y	Y	Y	
	Henley Wood	25				x
	Holborough	26				x
	Jarrow A	86	Y			
	Little Eriswell	28	Y	Y	Y	
	Machrins	29	Y	Y	Y	
	Mill Hill	30	Y	Y	Y	
	Nazeingbury	31				x
	Norton	33	Y	Y	Y	
	Oakington	35		Y		
	Oxborough	36	Y			
	Rivenhall A	64	Y	Y	Y	
	South Acre	40				x
	Tanners Row	41	Y			
	Watchfield	43	Y	Y	Y	
	West Heslerton	44	Y	Y	Y	
	Whithorn A	88	Y			
	Worthy Park	45	Y	Y	Y	
	York Minster	46	Y	Y	Y	
	Totals:	**41**	**32**	**23**	**22**	**8**

Medieval Period	Site Name	Data-set / Site No.	Prevalence			
			Teeth	Skeletons	Both	Neither
Middle Medieval	Blackgate	52	Y	Y	Y	
	Golden Minster A	22		Y		
	Holy Trinity Priory	70	Y			
	Kneep	27	Y	Y	Y	
	North Elmham Park	32	Y	Y	Y	
	Norwich Castle	34	Y	Y	Y	
	Raunds Furnells	37	Y			
	Red Castle	38	Y	Y	Y	
	Rivenhall B	73	Y	Y	Y	
	School Street	39	Y	Y	Y	
	St. Andrew Fishergate P4	61	Y	Y	Y	
	Thetford	42	Y	Y	Y	
	Trowbridge	75	Y	Y	Y	
	Totals:	**13**	**12**	**11**	**10**	**0**
Late Medieval	Aberdeen Carmelite Friary	80	Y	Y	Y	
	Blackfriars C	60	Y	Y	Y	
	Blackfriars G	59	Y	Y	Y	
	Blackfriars I	79	Y	Y	Y	
	Brighton Hill South	78	Y	Y	Y	
	Chelmsford Dominican Priory	54				x
	Chevington Chapel	58	Y			
	Chichester	67	Y	Y	Y	
	Franciscan Church, Hartlepool	84				x
	Golden Minster B	63		Y		
	Golden Minster C	65		Y		
	Greyfriars	66	Y			
	Hull Priory	53	Y	Y	Y	
	Isle of Ensay	51	Y	Y	Y	
	Jarrow B	87	Y			
	Jewbury	49		Y		
	Linlithgow Carmelite Friary	81	Y	Y	Y	
	Milton Keynes Village	57				x
	Pennell Street	56	Y	Y	Y	
	Perth Carmelite Friary	82	Y	Y	Y	
	Rivenhall C	83	Y	Y	Y	
	Rivenhall D	74	Y	Y	Y	
	Royal Mint	68				x
	Spitalfields Market	71	Y	Y	Y	
	St. Andrew Fishergate P6	62	Y	Y	Y	
	St. Bartholomew's Hospital	85	Y	Y	Y	
	St. Giles Hospital	72				x
	St. Helen-on-the-Walls	50	Y	Y	Y	
	St. Leonard's Hospital	77	Y	Y	Y	
	St. Mary Spital	48				x
	Stratford Langthorne Abbey	69	Y			
	Taunton Priory	76		Y		
	Whithorn B	47	Y			
	Ysgol Twm o'r Nant	55	Y			
	Totals:	**34**	**24**	**22**	**18**	**6**

No. = Number; **Y** = Yes; **x** = None.

Appendix 4 : Sites with Data on the Prevalence of Caries in Teeth (2 pages).

Medieval Period	Site Name	Data-set / Site No.	Caries Prevalence for Teeth From:			Skeletons
			Adult	Male	Female	
Early Medieval	Addingham	1	Y*	Y	Y	
	Apple Down	3	Y			
	Beckford A	4	Y*	Y	Y	Y
	Berinsfield	6	Y	Y	Y	Y
	Binchester	8	Y	Y	Y	
	Broughton Lodge	9	Y	Y	Y	Y
	Burgh Castle	11	Y*	Y	Y	Y
	Butler's Field	12	Y	Y	Y	Y
	Caister-on-Sea	13	Y*	Y	Y	Y
	Castledyke South	14	Y	Y	Y	Y
	Collingbourne Ducis	16	Y	Y	Y	Y
	Eccles	18	Y*	Y	Y	
	Empingham II	20	Y	Y	Y	Y
	Hallow Hill	24	Y			Y
	Jarrow A	86	Y*	Y	Y	
	Little Eriswell	28	Y*	Y	Y	Y
	Machrins	29	Y*		Y	Y
	Mill Hill	30	Y	Y	Y	Y
	Norton	33	Y			Y
	Oxborough	36	Y			
	Rivenhall A	64	Y	Y	Y	Y
	Tanners Row	41	Y*	Y	Y	
	Watchfield	43	Y	Y	Y	Y
	Whithorn A	88	Y			
	Worthy Park	45	Y	Y	Y	Y
	Totals:	**25**	**25**	**19**	**20**	**17**
Middle Medieval	Holy Trinity Priory	70	Y			
	Kneep	27	Y*		Y	Y
	North Elmham Park	32	Y*	Y	Y	Y
	Norwich Castle	34	Y	Y	Y	Y
	Raunds Furnells	37	Y*	Y	Y	
	Rivenhall B	73	Y	Y	Y	Y
	School Street	39	Y	Y	Y	Y
	St. Andrew Fishergate P4	61	Y*	Y	Y	Y
	Thetford	42	Y			Y
	Trowbridge	75	Y*			Y
	Totals:	**10**	**10**	**6**	**7**	**8**

Medieval Period	Site Name	Data-set / Site No.	Caries Prevalence for Teeth From:			Skeletons
			Adult	Male	Female	
Late Medieval	Aberdeen Carmelite Friary	80	Y	Y	Y	Y
	Blackfriars C	60	Y*	Y	Y	Y
	Blackfriars G	59	Y	Y	Y	Y
	Blackfriars I	79	Y	Y	Y	Y
	Brighton Hill South	78	Y			Y
	Chevington Chapel	58	Y	Y	Y	
	Chichester	67	Y*	Y	Y	Y
	Greyfriars	66	Y*	Y	Y	
	Hull Priory	53	Y*	Y	Y	Y
	Isle of Ensay	51	Y			Y
	Jarrow B	87	Y*	Y	Y	
	Linlithgow Carmelite Friary	81	Y	Y	Y	Y
	Pennell Street	56	Y	Y	Y	Y
	Perth Carmelite Friary	82	Y	Y	Y	Y
	Rivenhall C	83	Y*	Y	Y	Y
	Rivenhall D	74	Y*	Y	Y	Y
	Spitalfields Market	71	Y	Y	Y	Y
	St Helen-on-the-Walls	50	Y			Y
	St. Andrew Fishergate P6	62	Y*	Y	Y	Y
	St. Leonard's Hospital	77	Y*			Y
	Whithorn B	47	Y			
	Ysgol Twm o'r Nant	55	Y			
	Totals:	**22**	**22**	**16**	**16**	**17**

No. = Number; **Y** = Yes; **Y*** = sexed adults only.

Appendix 5 : Sites selected for analysis (2 pages).

Medieval Period	Site Name	Data-set / Site No.	Caries Prevalence for Teeth From:			Skeletons
			Adults	Male	Female	
Early Medieval	Addingham	1	Y*	Y	Y	
	Apple Down	3	Y			
	Beckford A	4	Y*	Y	Y	Y
	Berinsfield	6	Y	Y	Y	Y
	Binchester	8	Y	Y	Y	
	Broughton Lodge	9	Y	Y	Y	Y
	Burgh Castle	11	Y*	Y	Y	Y
	Butler's Field	12	Y	Y	Y	Y
	Caister-on-Sea	13	Y*	Y	Y	Y
	Castledyke South	14	Y	Y	Y	Y
	Collingbourne Ducis	16	Y	Y	Y	Y
	Eccles	18	Y*	Y	Y	
	Empingham II	20	Y	Y	Y	Y
	Hallow Hill	24	Y			Y
	Jarrow A	86	Y*	Y	Y	
	Little Eriswell	28	Y*	Y	Y	Y
	Mill Hill	30	Y	Y	Y	Y
	Norton	33	Y			Y
	Rivenhall A	64	Y	Y	Y	Y
	Tanners Row	41	Y*	Y	Y	
	Watchfield	43	Y	Y	Y	Y
	Whithorn A	88	Y			
	Worthy Park	45	Y	Y	Y	Y
	Totals:	**23**	**23**	**19**	**19**	**16**
	Holy Trinity Priory	70	Y			
Middle Medieval	North Elmham Park	32	Y*	Y	Y	Y
	Norwich Castle	34	Y	Y	Y	Y
	Raunds Furnells	37	Y*	Y	Y	
	Rivenhall B	73	Y	Y	Y	Y
	School Street	39	Y	Y	Y	Y
	St. Andrew Fishergate P4	61	Y*	Y	Y	Y
	Thetford	42	Y			Y
	Trowbridge	75	Y*			Y
	Totals:	**9**	**9**	**6**	**6**	**7**

Medieval Period	Site Name	Data-set / Site No.	Caries Prevalence for Teeth From:			Skeletons
			Adults	Male	Female	
Late Medieval	Aberdeen Carmelite Friary	80	Y	Y	Y	Y
	Blackfriars C	60	Y*	Y	Y	Y
	Blackfriars G	59	Y	Y	Y	Y
	Blackfriars I	79	Y	Y	Y	Y
	Brighton Hill South	78	Y			Y
	Chevington Chapel	58	Y	Y	Y	
	Chichester	67	Y*	Y	Y	Y
	Greyfriars	66	Y*	Y	Y	
	Hull Priory	53	Y*	Y	Y	Y
	Isle of Ensay	51	Y			Y
	Jarrow B	87	Y*	Y	Y	
	Linlithgow Carmelite Friary	81	Y	Y	Y	Y
	Pennell Street	56	Y	Y	Y	Y
	Perth Carmelite Friary	82	Y	Y	Y	Y
	Rivenhall C	83	Y*	Y	Y	Y
	Rivenhall D	74	Y*	Y	Y	Y
	Spitalfields Market	71	Y	Y	Y	Y
	St Helen-on-the-Walls	50	Y			Y
	St. Andrew Fishergate P6	62	Y*	Y	Y	Y
	St. Leonard's Hospital	77	Y*			Y
	Whithorn B	47	Y			
	Totals:	**21**	**21**	**16**	**16**	**17**

No. = Number; **Y** = Yes; **Y*** = sexed adults only.

Appendix 6 : Caries Prevalence in Early, Middle and Late Medieval periods.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Early	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
	3	Apple Down	216	2122	10.2%						
	4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
	6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
	8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
	9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
	12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
	13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
	14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
	16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
	18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
	20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
	24	Hallow Hill	38	951	4.0%						
	86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
	28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
	30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
	33	Norton	45	1325	3.4%						
	64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
	41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
	43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
	88	Whithorn A	32	499	6.4%						
	45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
	23	**Totals**	**1172**	**23470**	**5.0%**	**389**	**8740**	**4.5%**	**426**	**8952**	**4.8%**
Middle	70	Holy Trinity Priory	11	366	3.0%						
	32	North Elmham Park	102	1577	6.5%	53	778	6.8%	49	799	6.1%
	34	Norwich Castle	52	750	6.9%	23	409	5.6%	22	281	7.8%
	37	Raunds Furnells	142	3250	4.4%	79	1875	4.2%	63	1375	4.6%
	73	Rivenhall B	22	138	15.9%	9	68	13.2%	9	54	16.7%
	39	School Street	68	680	10.0%	43	285	15.1%	22	341	6.5%
	61	St. Andrew Fishergate P4	60	1406	4.3%	20	900	2.2%	40	506	7.9%
	42	Thetford	69	924	7.5%						
	75	Trowbridge	494	2031	24.3%						
	9	**Totals**	**1020**	**11122**	**9.2%**	**227**	**4315**	**5.3%**	**205**	**3356**	**6.1%**
Late	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
	60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
	79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
	78	Brighton Hill South	5	312	1.6%						
	58	Chevington Chapel	51	469	10.9%	18	167	10.8%	31	200	15.5%
	67	Chichester	647	3902	16.6%	420	2826	14.9%	227	1076	21.1%
	66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
	53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
	51	Isle of Ensay	160	1437	11.1%						
	87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
	81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
	56	Pennell Street	38	569	6.7%	14	204	6.9%	23	304	7.6%
	82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
	83	Rivenhall C	48	198	24.2%	36	123	29.3%	12	75	16.0%
	74	Rivenhall D	30	178	16.9%	19	122	15.6%	11	56	19.6%
	71	Spitalfields Market	291	3159	9.2%	121	1315	9.2%	152	1101	13.8%
	50	St Helen-on-the-Walls	345	7806	4.4%						
	62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
	77	St. Leonard's Hospital	45	614	7.3%						
	47	Whithorn B	749	9520	7.9%						
	21	**Totals**	**3577**	**43043**	**8.3%**	**1357**	**14162**	**9.6%**	**861**	**7509**	**11.5%**

No. Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 7 : Caries Prevalence in Early Saxon/Early-Middle Saxon and Middle Saxon/Middle-Late Saxon (Early Medieval Group Sub-Periods).

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Early-Middle Saxon	4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
	6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
	9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
	20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
	28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
	30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
	43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
	45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
	3	Apple Down	216	2122	10.2%						
	12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
	14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
	16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
	88	Whithorn A	32	499	6.4%						
	33	Norton	45	1325	3.4%						
	14	**Totals**	**898**	**15806**	**5.7%**	**271**	**5041**	**5.4%**	**310**	**5989**	**5.2%**
Mid-Late Saxon	18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
	86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
	64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
	8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
	13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
	41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
	24	Hallow Hill	38	951	4.0%						
	9	**Totals**	**274**	**7664**	**3.6%**	**118**	**3699**	**3.2%**	**116**	**2963**	**3.9%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 8 : Caries Prevalence in Early Saxon, Early-Middle Saxon, Middle Saxon and Middle-Late Saxon (Early Medieval Divided Sub-Periods).

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Early Saxon	4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
	6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
	9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
	20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
	28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
	30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
	43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
	45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
	8	**Totals**	**244**	**6261**	**3.9%**	**113**	**2973**	**3.8%**	**118**	**2747**	**4.3%**
Early-Mid Saxon	3	Apple Down	216	2122	10.2%						
	12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
	14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
	16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
	33	Norton	45	1325	3.4%						
	88	Whithorn A	32	499	6.4%						
	6	**Totals**	**654**	**9545**	**6.9%**	**158**	**2068**	**7.6%**	**192**	**3242**	**5.9%**
Mid Saxon	18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
	24	Hallow Hill	38	951	4.0%						
	86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
	64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
	4	**Totals**	**144**	**3363**	**4.3%**	**51**	**1360**	**3.8%**	**54**	**1021**	**5.3%**
Mid-Late Saxon	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
	8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
	13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
	41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
	5	**Totals**	**130**	**4301**	**3.0%**	**67**	**2339**	**2.9%**	**62**	**1942**	**3.2%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 9 : Caries prevalence in the Middle Medieval sub-periods.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	**P**	**%**	**C**	**P**	**%**	**C**	**P**	**%**
Late Saxon	32	North Elmham Park	102	1577	6.5%	53	778	6.8%	49	799	6.1%
	34	Norwich Castle	52	750	6.9%	23	409	5.6%	22	281	7.8%
	37	Raunds Furnells	142	3250	4.4%	79	1875	4.2%	63	1375	4.6%
	39	School Street	68	680	10.0%	43	285	15.1%	22	341	6.5%
	42	Thetford	69	924	7.5%						
	5	**Totals**	**433**	**7181**	**6.0%**	**198**	**3347**	**5.9%**	**156**	**2796**	**5.6%**
Early-Late Medieval	70	Holy Trinity Priory	11	366	3.0%						
	73	Rivenhall B	22	138	15.9%	9	68	13.2%	9	54	16.7%
	61	St. Andrew Fishergate P4	60	1406	4.3%	20	900	2.2%	40	506	7.9%
	75	Trowbridge	494	2031	24.3%						
	4	**Totals**	**587**	**3941**	**14.9%**	**29**	**968**	**3.0%**	**49**	**560**	**8.8%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 10 : Caries prevalence in the Late Medieval cemetery types.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Ca	47	Whithorn B	749	9520	7.9%						
	1	**Totals**	**749**	**9520**	**7.9%**						
Church	78	Brighton Hill South	5	312	1.6%						
	58	Chevington Chapel	51	469	10.9%	18	167	10.8%	31	200	15.5%
	51	Isle of Ensay	160	1437	11.1%						
	56	Pennell Street	38	569	6.7%	14	204	6.9%	23	304	7.6%
	83	Rivenhall C	48	198	24.2%	36	123	29.3%	12	75	16.0%
	74	Rivenhall D	30	178	16.9%	19	122	15.6%	11	56	19.6%
	50	St Helen-on-the-Walls	345	7806	4.4%						
	7	**Totals**	**677**	**10969**	**6.2%**	**87**	**616**	**14.1%**	**77**	**635**	**12.1%**
Hospital	67	Chichester	647	3902	16.6%	420	2826	14.9%	227	1076	21.1%
	71	Spitalfields Market	291	3159	9.2%	121	1315	9.2%	152	1101	13.8%
	77	St. Leonard's Hospital	45	614	7.3%						
	3	**Totals**	**983**	**7675**	**12.8%**	**541**	**4141**	**13.1%**	**379**	**2177**	**17.4%**
Monastic	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
	60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
	79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
	66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
	53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
	87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
	81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
	82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
	62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
	10	**Totals**	**1168**	**14879**	**7.8%**	**729**	**9405**	**7.8%**	**405**	**4697**	**8.6%**

No. = Number; **Ca** = Cathedral; **C** = With Caries; **P** = Number of teeth present.

Appendix 11 : Caries prevalence in Early, Middle and Late Medieval non-monastic sites.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Early	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
	3	Apple Down	216	2122	10.2%						
	4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
	6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
	8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
	9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
	12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
	13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
	14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
	16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
	18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
	20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
	24	Hallow Hill	38	951	4.0%						
	28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
	30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
	33	Norton	45	1325	3.4%						
	64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
	41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
	43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
	45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
	21	**Totals**	**1134**	**22362**	**5.1%**	**385**	**8388**	**4.6%**	**424**	**8695**	**4.9%**
Middle	32	North Elmham Park	102	1577	6.5%	53	778	6.8%	49	799	6.1%
	34	Norwich Castle	52	750	6.9%	23	409	5.6%	22	281	7.8%
	37	Raunds Furnells	142	3250	4.4%	79	1875	4.2%	63	1375	4.6%
	73	Rivenhall B	22	138	15.9%	9	68	13.2%	9	54	16.7%
	39	School Street	68	680	10.0%	43	285	15.1%	22	341	6.5%
	61	St. Andrew Fishergate P4	60	1406	4.3%	20	900	2.2%	40	506	7.9%
	42	Thetford	69	924	7.5%						
	75	Trowbridge	494	2031	24.3%						
	8	**Totals**	**1009**	**10756**	**9.4%**	**227**	**4315**	**5.3%**	**205**	**3356**	**6.1%**
Late	78	Brighton Hill South	5	312	1.6%						
	58	Chevington Chapel	51	469	10.9%	18	167	10.8%	31	200	15.5%
	51	Isle of Ensay	160	1437	11.1%						
	56	Pennell Street	38	569	6.7%	14	204	6.9%	23	304	7.6%
	83	Rivenhall C	48	198	24.2%	36	123	29.3%	12	75	16.0%
	74	Rivenhall D	30	178	16.9%	19	122	15.6%	11	56	19.6%
	50	St Helen-on-the-Walls	345	7806	4.4%						
	7	**Totals**	**677**	**10969**	**6.2%**	**87**	**616**	**14.1%**	**77**	**635**	**12.1%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 12 : Caries prevalence in Early, Middle and Late monastic sites.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Early	86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
	88	Whithorn B	32	499	6.4%						
	2	**Totals**	**38**	**1108**	**3.4%**	**4**	**352**	**1.1%**	**2**	**257**	**0.8%**
Middle	70	Holy Trinity Priory	11	366	3.0%						
	1	**Totals**	**11**	**366**	**3.0%**						
Late	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
	60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
	79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
	66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
	53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
	87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
	81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
	82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
	62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
	10	**Totals**	**1168**	**14879**	**7.8%**	**729**	**9405**	**7.8%**	**405**	**4697**	**8.6%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 13 : Caries prevalence in Late Medieval monastic orders.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Augustinian	53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
	1	**Totals**	**214**	**2945**	**7.3%**	**170**	**2159**	**7.9%**	**44**	**786**	**5.6%**
Benedictine.	87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
	1	**Totals**	**42**	**957**	**4.4%**	**9**	**400**	**2.3%**	**30**	**524**	**5.7%**
Carmelite	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
	81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
	82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
	3	**Totals**	**99**	**2409**	**4.1%**	**28**	**989**	**2.8%**	**49**	**912**	**5.4%**
Dominican	60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
	79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
	66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
	4	**Totals**	**457**	**5623**	**8.1%**	**275**	**3594**	**7.7%**	**173**	**1793**	**9.6%**
Gilbertine	62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
	1	**Totals**	**356**	**2945**	**12.1%**	**247**	**2263**	**10.9%**	**109**	**682**	**16.0%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 14 : Caries prevalence in Early, Middle and Late Medieval coastal and inland sites.

Medieval Period		Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
				C	P	%	C	P	%	C	P	%
Coast	Early	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
		13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
		14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
		24	Hallow Hill	38	951	4.0%						
		86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
		30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
		33	Norton	45	1325	3.4%						
		88	Whithorn A	32	499	6.4%						
		8	**Totals**	**313**	**9056**	**3.5%**	**103**	**3067**	**3.4%**	**90**	**2935**	**3.1%**
	Middle	39	School Street	68	680	10.0%	43	285	15.1%	22	341	6.5%
		1	**Totals**	**68**	**680**	**10.0%**	**43**	**285**	**15.1%**	**22**	**341**	**6.5%**
	Late	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
		60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
		79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
		58	Chevington Chapel	51	469	10.9%	18	167	10.8%	31	200	15.5%
		67	Chichester	647	3902	16.6%	420	2826	14.9%	227	1076	21.1%
		53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
		51	Isle of Ensay	160	1437	11.1%						
		87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
		81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
		47	Whithorn B	749	9520	7.9%						
		10	**Totals**	**2303**	**25742**	**8.9%**	**869**	**9235**	**9.4%**	**497**	**4806**	**10.3%**
Inland	Early	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
		3	Apple Down	216	2122	10.2%						
		4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
		6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
		8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
		9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
		12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
		16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
		18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
		20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
		28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
		64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
		41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
		43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
		45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
		15	**Totals**	**859**	**14414**	**6.0%**	**286**	**5673**	**5.0%**	**336**	**6017**	**5.6%**
	Middle	70	Holy Trinity Priory	11	366	3.0%						
		32	North Elmham Park	102	1577	6.5%	53	778	6.8%	49	799	6.1%
		34	Norwich Castle	52	750	6.9%	23	409	5.6%	22	281	7.8%
		37	Raunds Furnells	142	3250	4.4%	79	1875	4.2%	63	1375	4.6%
		73	Rivenhall B	22	138	15.9%	9	68	13.2%	9	54	16.7%
		61	St. Andrew Fishergate P4	60	1406	4.3%	20	900	2.2%	40	506	7.9%
		42	Thetford	69	924	7.5%						
		75	Trowbridge	494	2031	24.3%						
		8	**Totals**	**952**	**10442**	**9.1%**	**184**	**4030**	**4.6%**	**183**	**3015**	**6.1%**
	Late	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
		78	Brighton Hill South	5	312	1.6%						
		66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
		56	Pennell Street	38	569	6.7%	14	204	6.9%	23	304	7.6%
		82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
		83	Rivenhall C	48	198	24.2%	36	123	29.3%	12	75	16.0%
		74	Rivenhall D	30	178	16.9%	19	122	15.6%	11	56	19.6%
		71	Spitalfields Market	291	3159	9.2%	121	1315	9.2%	152	1101	13.8%
		50	St Helen-on-the-Walls	345	7806	4.4%						
		62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
		77	St. Leonard's Hospital	45	614	7.3%						
		11	**Totals**	**1274**	**17301**	**7.4%**	**488**	**4927**	**9.9%**	**364**	**2703**	**13.5%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 15 : Caries prevalence in the Early Medieval regions.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Far North	8	Binchester	8	259	3.1%	1	121	0.8%	6	118	5.1%
	24	Hallow Hill	38	951	4.0%	-	-	-	-	-	-
	86	Jarrow A	6	609	1.0%	4	352	1.1%	2	257	0.8%
	33	Norton	45	1325	3.4%	-	-	-	-	-	-
	88	Whithorn A	32	499	6.4%	-	-	-	-	-	-
	5	**Totals**	**129**	**3643**	**3.5%**	**5**	**473**	**1.1%**	**8**	**375**	**2.1%**
North/ North West	1	Addingham	36	528	6.8%	14	292	4.8%	22	236	9.3%
	14	Castledyke South	110	1890	5.8%	44	673	6.5%	61	1053	5.8%
	41	Tanners Row	30	408	7.4%	18	210	8.6%	12	198	6.1%
	3	**Totals**	**176**	**2826**	**6.2%**	**76**	**1175**	**6.5%**	**95**	**1487**	**6.4%**
Eastern/ Central Eastern	9	Broughton Lodge	21	566	3.7%	6	218	2.8%	11	204	5.4%
	11	Burgh Castle	25	1347	1.9%	18	793	2.3%	7	554	1.3%
	13	Caister-on-Sea	31	1759	1.8%	16	923	1.7%	15	836	1.8%
	20	Empingham II	68	1557	4.4%	30	767	3.9%	34	664	5.1%
	28	Little Eriswell	4	235	1.7%	3	129	2.3%	1	106	0.9%
	64	Rivenhall A	18	379	4.7%	10	237	4.2%	7	111	6.3%
	6	**Totals**	**167**	**5843**	**2.9%**	**83**	**3067**	**2.7%**	**75**	**2475**	**3.0%**
Central Southern	3	Apple Down	216	2122	10.2%	-	-	-	-	-	-
	4	Beckford A	2	415	0.5%	2	211	0.9%	0	204	0.0%
	6	Berinsfield	40	1097	3.6%	15	518	2.9%	25	503	5.0%
	12	Butler's Field	204	3285	6.2%	88	1173	7.5%	114	2019	5.6%
	16	Collingbourne Ducis	47	424	11.1%	26	222	11.7%	17	170	10.0%
	43	Watchfield	41	472	8.7%	11	232	4.7%	25	185	13.5%
	45	Worthy Park	42	1243	3.4%	25	572	4.4%	17	646	2.6%
	7	**Totals**	**592**	**9058**	**6.5%**	**167**	**2928**	**5.7%**	**198**	**3727**	**5.3%**
South East	18	Eccles	82	1424	5.8%	37	771	4.8%	45	653	6.9%
	30	Mill Hill	26	676	3.8%	21	326	6.4%	5	235	2.1%
	2	**Totals**	**108**	**2100**	**5.1%**	**58**	**1097**	**5.3%**	**50**	**888**	**5.6%**

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 16 : Caries prevalence in the Middle Medieval regions.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Far North	-	-	-	-	-	-	-	-	-	-	-
	0	**Totals**									
North/ North West	61	St. Andrew Fishergate P4	60	1406	4.3%	20	900	2.2%	40	506	7.9%
	1	**Totals**	**60**	**1406**	**4.3%**	**20**	**900**	**2.2%**	**40**	**506**	**7.9%**
Eastern/ Central Eastern	32	North Elmham Park	102	1577	6.5%	53	778	6.8%	49	799	6.1%
	34	Norwich Castle	52	750	6.9%	23	409	5.6%	22	281	7.8%
	37	Raunds Furnells	142	3250	4.4%	79	1875	4.2%	63	1375	4.6%
	39	School Street	68	680	10.0%	43	285	15.1%	22	341	6.5%
	42	Thetford	69	924	7.5%	-	-	-	-	-	-
	70	Holy Trinity Priory	11	366	3.0%	-	-	-	-	-	-
	73	Rivenhall B	22	138	15.9%	9	68	13.2%	9	54	16.7%
	7	**Totals**	**466**	**7685**	**6.1%**	**207**	**3415**	**6.1%**	**165**	**2850**	**5.8%**
Central Southern	75	Trowbridge	494	2031	24.3%	-	-	-	-	-	-
	1	**Totals**	**494**	**2031**	**24.3%**						
South East	-	-	-	-	-	-	-	-	-	-	-
	0	**Totals**									

No. = Number; **C** = With Caries; **P** = Number of teeth present.

Appendix 17 : Caries prevalence in the Late Medieval regions.

Medieval Period	Data-set / Site No.	Site Name	Teeth from Adults			Teeth from Males			Teeth from Females		
			C	P	%	C	P	%	C	P	%
Far North	80	Aberdeen Carmelite Friary	29	815	3.6%	10	530	1.9%	17	266	6.4%
	60	Blackfriars C	39	1315	3.0%	22	721	3.1%	17	517	3.3%
	58	Chevington Chapel	51	469	10.9%	18	167	10.8%	31	200	15.5%
	51	Isle of Ensay	160	1437	11.1%	-	-	-	-	-	-
	87	Jarrow B	42	957	4.4%	9	400	2.3%	30	524	5.7%
	81	Linlithgow Carmelite Friary	70	1465	4.8%	18	393	4.6%	32	583	5.5%
	82	Perth Carmelite Friary	0	129	0.0%	0	66	0.0%	0	63	0.0%
	47	Whithorn B	749	9520	7.9%	-	-	-	-	-	-
	8	**Totals**	**1140**	**16107**	**7.1%**	**77**	**2277**	**3.4%**	**127**	**2153**	**5.9%**
North/Norh West	66	Greyfriars	38	422	9.0%	23	366	6.3%	15	56	26.8%
	53	Hull Priory	214	2945	7.3%	170	2159	7.9%	44	786	5.6%
	56	Pennell Street	38	569	6.7%	14	204	6.9%	23	304	7.6%
	50	St Helen-on-the-Walls	345	7806	4.4%						
	62	St. Andrew Fishergate P6	356	2945	12.1%	247	2263	10.9%	109	682	16.0%
	77	St. Leonard's Hospital	45	614	7.3%	-	-	-	-	-	-
	6	**Totals**	**1036**	**15301**	**6.8%**	**454**	**4992**	**9.1%**	**191**	**1828**	**10.4%**
Eastern / Central Eastern	79	Blackfriars I	302	2917	10.4%	202	2039	9.9%	99	854	11.6%
	83	Rivenhall C	48	198	24.2%	36	123	29.3%	12	75	16.0%
	74	Rivenhall D	30	178	16.9%	19	122	15.6%	11	56	19.6%
	71	Spitalfields Market	291	3159	9.2%	121	1315	9.2%	152	1101	13.8%
	4	**Totals**	**671**	**6452**	**10.4%**	**378**	**3599**	**10.5%**	**274**	**2086**	**13.1%**
Central Southern	59	Blackfriars G	78	969	8.0%	28	468	6.0%	42	366	11.5%
	78	Brighton Hill South	5	312	1.6%	-	-	-	-	-	-
	67	Chichester	647	3902	16.6%	420	2826	14.9%	227	1076	21.1%
	3	**Totals**	**730**	**5183**	**14.1%**	**448**	**3294**	**13.6%**	**269**	**1442**	**18.7%**
South East	-	-	-	-	-	-	-	-	-	-	-
	0	**Totals**									

No. = Number; **C** = With Caries; **P** = Number of teeth present.